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# **Rotorcraft Aeromechanical Stability-Methodology Assessment: Phase 2 Workshop**

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**William G. Bousman**

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William G. Bousman, Ames Research Center, Moffett Field, California

March 1990



National Aeronautics and  
Space Administration

**Ames Research Center**  
Moffett Field, California 94035-1000



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MOFFETT FIELD, CA 94035-1099

# **ROTORCRAFT AEROMECHANICAL STABILITY - METHODOLOGY ASSESSMENT PHASE 2 WORKSHOP**

**William G. Bousman  
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and  
Aeroflightdynamics Directorate  
U.S. Army Research and Technology Activity (AVSCOM)**

## **Introduction**

A workshop was held at Ames Research Center August 2-3, 1988 to discuss the results of the Methodology Assessment Phase 2 Continuation. This workshop was a follow-on to the original Methodology Assessment reported in Ref. 1. The present volume contains the predictions that were obtained under the continuation efforts.

The original Integrated Technology Rotor (ITR) Methodology Assessment was a Government-funded study to assess the capability of industry analyses to predict the aeroelastic and aeromechanical stability of rotorcraft. Six different sets of experimental data were used as a baseline ranging from a hingeless rotor model in hover to data on a full-scale bearingless rotor in forward flight as shown in Table 1. For each data set, A through F, several cases or configuration variations were identified to enable comparisons for a range of rotor aeroelastic effects. Analyses from Bell Helicopter Textron, Boeing Helicopters, McDonnell Douglas Helicopter Company, and Sikorsky Aircraft were compared with the data. The first workshop to discuss these results was held in June 1983 at Ames Research Center and was reported in Ref. 1.

Following the original assessment, two data sets were selected for a significantly more detailed comparison in an effort referred to as the Phase 1 Continuation. The first set selected (Data Set A, Case 6) was for the torsionally-soft hingeless rotor model in hover with a soft pitch flexure and negative droop. This particular case had shown the greatest discrepancies in the Methodology Assessment results. The second case (Data Set C, Case 3) was from an aeromechanical rotor-body stability model test where there was extensive data available on modes other than the lead-lag regressing mode. Whereas in the original Methodology Assessment the basis of comparison was the damping of the least stable mode, in the Phase 1 Continuation the damping and frequency of all the rotor modes in the frequency range of the least stable mode were examined.

A Phase 2 Continuation effort followed the Phase 1 work. Additional computations were made with the torsionally-soft hingeless rotor model of Data Set A. The acquisition of frequency data in a vacuum test of this model rotor (Ref. 2) prompted inclusion of new calculations to compare with these data as well. A simplified hypothetical version of the torsionally-soft rotor model was also specified that retained the aeroelastic coupling effects that had caused difficulties in the torsionally-soft rotor comparisons but eliminated the unimportant blade root hardware that complicated the assessments. Finally, two new matched-stiffness configurations were added for the aeromechanical stability test (Data Set C) that had not been examined previously.

Table 1. - Experimental Data Sets

DATA SET	ROTOR TYPE	FUSELAGE COUPLING	FLIGHT CONDITION	SCALE	SOURCE
A	Hingeless	Isolated	Hover	Model	Aeroflightdynamics
B	Hingeless	Rotor-Body	Hover	Model	Aeroflightdynamics
C	Hingeless	Rotor-Body	Hover	Model	Aeroflightdynamics
D	Bearingless	Isolated	Hover	Model	Aeroflightdynamics
E	Bearingless	Rotor-Body	Hover/Fwd Flt	Model	Boeing Helicopters
F	Bearingless	Rotor-Body	Hover/Fwd Flt	Full	Boeing Helicopters

The purpose of this report was to collect and publish the results of the Phase 1 and Phase 2 Methodology Assessment Continuation efforts for use by future investigators. Discussion of these results is not provided in this document; conclusions about the relative merits of the various prediction codes, the quality of the predicted results, or explanation of the sources of differences between predicted and measured data are left to the reader. A full description of the experimental data sets, the experiments themselves, and the prediction codes can be found in Ref. 1. Although the analysis results presented in the figures contained herein should be self-explanatory, additional discussion of some details may be found in Ref. 1. This report is intended to be a companion to that report.

The report is organized into four sections presenting the results for the predictions of the four data sets addressed in the Phase 1 and Phase 2 Continuations.

### **Torsionally-Soft Hingeless Rotor Model**

The damping predictions shown in the original Methodology Assessment for the torsionally-soft rotor model (Data Set A) were obtained for six different cases or configurations. For the Phase 1 and 2 Continuations, more detailed predictions were made for Cases 2 and 6, and these predictions included the damping and frequency of the flap, lead-lag, and torsion modes as well as the blade equilibrium flap, lead-lag, and torsional deflections. The additional parameters calculated in the continuation were intended to help understand the variations in the original lead-lag damping results. The two cases studied, both with the soft pitch-flexure configuration, were Case 2 without precone or droop and Case 6 with  $-5^\circ$  droop and no precone. The Case 6 configuration has the largest aeroelastic coupling and showed the widest variations in predicted lead-lag damping. The calculations shown here are outlined in Table 2. The task numbers shown in Table 2 refer to the tasks listed in the continuation statement of work. The calculations are shown on the pages indicated in the table. A symbol is shown on the torsionally-soft rotor plots that represents the case plotted. The middle section of the symbol represents the root configuration and is open for cases with a soft pitch-flexure (Cases 2 and 6). The right hand section of the symbol represents the blade and is horizontal for Case 2 (no precone or droop) and is canted upwards for Case 6 ( $-5^\circ$  droop).

Table 2. – Torsionally-Soft Rotor Hover Test (Data Set A)

CASE	PITCH FLEXURE	PRECONE $\beta_{pc}$ , deg	DROOP $\beta_d$ , deg	PHASE 2	PAGES
1	stiff	0.0	0.0	–	–
2	soft	0.0	0.0	Tasks 86d, 86e	10-107
3	stiff	5.0	0.0	–	–
4	soft	5.0	0.0	–	–
5	stiff	0.0	-5.0	–	–
6	soft	0.0	-5.0	Tasks 86f, 86g	108-205

The same model properties were used for the Phase 2 calculations as were used in the original Methodology Assessment (Ref. 1) except the analysts were instructed to adjust the the chordwise structural properties so that the predicted nonrotating lead-lag frequency matched the measured Case 2 value. The chordwise properties were then fixed for the rest of the torsionally-soft rotor cases. For the Case 2 configuration without precone or droop, the Phase 2 comparisons of theory and experiment for Task 86d are shown on pages 10 to 44. Nonlinear aerodynamic section properties were used for these calculations, that is,

$$c_l = 6\alpha - (\text{sgn}\alpha) 10\alpha^2$$

$$c_d = 0.01 + 11.1|\alpha|^3$$

The same comparisons were made in Task 86e except that linear aerodynamic section properties were used

$$c_l = 2\pi\alpha$$

$$c_d = 0.008$$

The pitching moment was assumed to be zero and the section properties were assumed independent of Mach number for both tasks. The Task 86e calculations are shown on pages 45 to 107. Included in these calculations are comparisons of the linear and nonlinear predictions for each analyst.

Calculations made with nonlinear section properties for Case 6 (Task 86f) are given on pages 108 to 142. The predictions made with linear aerodynamic section properties (Task 86g) are on pages 143 to 205. Again, these latter calculations include comparisons of the linear and nonlinear predictions for each analyst.

### Torsionally-Soft Hingeless Rotor Model in Vacuum

Calculations of flap, lead-lag, and torsion frequencies in vacuum were made during the Phase 2 continuation and these are compared here to experimental measurements that have been obtained on the torsionally-soft rotor model (Ref. 2). These results provide an opportunity to compare basic rotor structural and inertial analyses without the additional uncertainties of aerodynamic modeling. The calculations are shown for the cases outlined in Table 3. The comparisons for Case 2 (Task 86b) are on pages 206 to 215. The Case 6 comparisons (Task 86c) are on pages 216 to 225.

Table 3. – Torsionally-Soft Rotor Vacuum Test

CASE	PITCH FLEXURE	PRECONE $\beta_{pc}$ , deg	DROOP $\beta_d$ , deg	PHASE 2	PAGES
2	soft	0.0	0.0	Task 86b	206-215
6	soft	0.0	-5.0	Task 86c	216-225

### Hypothetical Torsionally-Soft Hingeless Rotor

Although the torsionally-soft hingeless rotor model represents an almost ideal configuration intended for research purposes, several physical details such as the pitch flexure and blade root retention hardware require some care to properly represent in prediction codes. To remove these complications and provide a more unambiguous basis for analysis comparisons, a hypothetical rotor model was specified for the Phase 2 calculations. This rotor shows a number of simplifications from the actual torsionally-soft rotor model. A sketch of the hypothetical model is shown in Fig. 1 to illustrate the coordinate system that defines the blade pitch and preconer angles. The blade of the hypothetical rotor model is defined in a coordinate system  $b_j^P$ , where the blade axis system is defined relative to the coordinate system by

$$b_i^P = [C_{ij}] b_j^F$$

$$[C_{ij}] = \begin{bmatrix} \cos \theta & \sin \theta & 0 \\ -\sin \theta & \cos \theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos \beta & 0 & -\sin \beta \\ 0 & 1 & 0 \\ \sin \beta & 0 & \cos \beta \end{bmatrix}$$

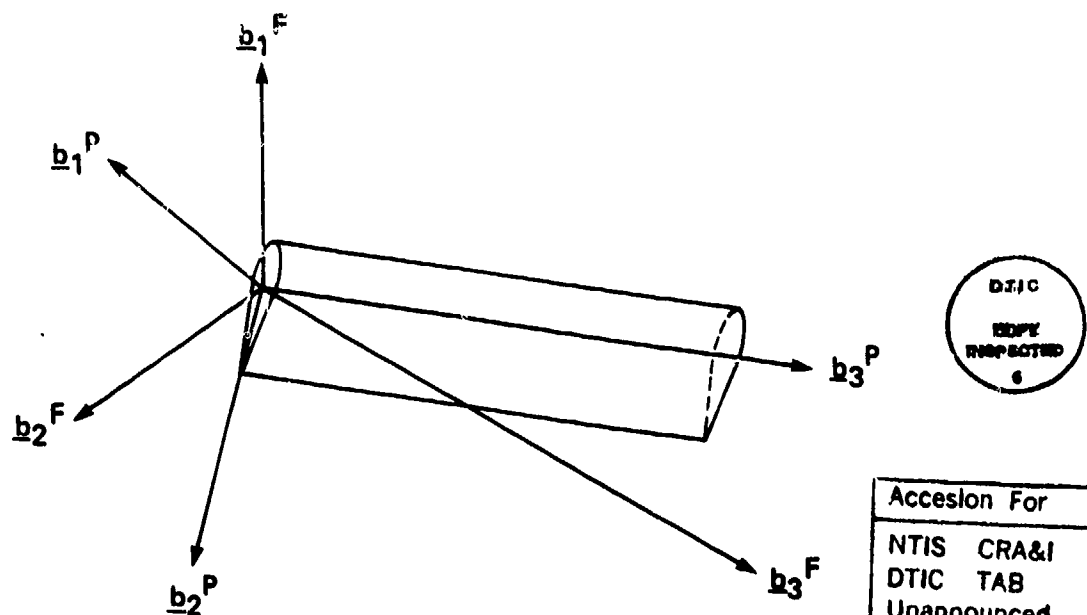


Figure 1. - Schematic of hypothetical rotor model.

Table 4. - Hypothetical Rotor Properties

Radius, in	36.0
Chord, in	3.5
Blade mass, lb <sub>m</sub> /in	0.0167
Blade inertia about elastic axis, lb <sub>m</sub> -in <sup>2</sup> /in	0.0167
Flap stiffness, lb-in <sup>2</sup>	6000.
Chord stiffness, lb-in <sup>2</sup>	100000.
Torsional stiffness, lb-in <sup>2</sup>	1800.
Lift curve slope	6.28
Drag coefficient	0.01
Structural damping	0.0

where  $\theta$  is the blade pitch angle and  $\beta$  is the precone angle. The blade properties are given in Table 4. The blade c.g., and the elastic and tensile axes are at the 25% chord.

Two cases were calculated for the hypothetical rotor as shown in Table 5. The calculations are shown on pages 226-231 for the case without precone (Task 86h) and on pages 232-237 for the case with 5° precone (Task 86i). As in the case of the torsionally-soft rotor calculations a symbol is used on the plots to represent the case being examined. As the hypothetical rotor does not have a pitch flexure there is no middle section to the symbol. The right hand section is either horizontal for zero precone cases or canted up for cases with precone.

Table 5. - Hypothetical Rotor

PRECONE $\beta_{pc}$ , deg	PHASE 2	PAGES
0.0	Task 86h	226-231
5.0	Task 86i	232-237

### Hingeless Rotor Body Model

Calculations of modal frequency and damping have been compared to the coupled rotor-body experimental model data of Ref. 3 in the Phase 1 and 2 Continuations. Calculations have been made for Case 3 of the original Methodology Assessment as well for configurations not previously examined. The calculation cases are outlined in Table 6. Tabulated parameters in Table 6 include the pitch-lag coupling,  $\theta_\zeta$ , and the elastic coupling,  $R$ .

Table 6. - Aeromechanical Stability

CONF. (Ref. 3)	FLAP & LAG STIFFNESSES	$\theta_\zeta$	$R$	METHODOLOGY ASSESSMENT CASES	PHASE 1	PHASE 2	PAGES
1	$\omega_{\beta_0} < \omega_{\zeta_0}$	0.0	0	1,2	-	-	-
2	$\omega_{\beta_0} < \omega_{\zeta_0}$	-0.4	0	3	Task 84-2	-	238-249
3	$\omega_{\beta_0} < \omega_{\zeta_0}$	-0.4	1	-	-	-	-
4	$\omega_{\beta_0} \approx \omega_{\zeta_0}$	0.0	0	-	-	-	-
5	$\omega_{\beta_0} \approx \omega_{\zeta_0}$	-0.4	0	-	-	Tasks 86j, 86k	250-267

The Task 84-2 calculations were made for a blade pitch angle of  $9^\circ$  and are compared to the data on pages 238 to 249. These results include frequency and damping of several modes in addition to the least stable mode that was presented in the original Methodology Assessment. The Phase 2 Continuation addressed a model configuration having roughly equal flap and lead-lag flexure bending stiffness levels. This "matched stiffness" configuration revealed evidence of a dynamic inflow mode that was later confirmed by analysis (Ref. 4). The Task 86j and 86k calculations were addressed to this matched stiffness configuration and included dynamic inflow models where available. For Task 86j the flap and lead-lag flexure thicknesses were adjusted from the Methodology Assessment model parameters to yield nonrotating flap and lead-lag frequencies of 7.04 and 6.64 Hz respectively. For Task 86k the adjustments were made to provide values of 6.73 and 6.64 Hz for the nonrotating flap and lead-lag frequencies. The Task 86j calculations were run for a pitch angle of  $9^\circ$  and are shown on pages 250 to 258. The Task 86k calculations were run for zero pitch and are shown on pages 259 to 267.

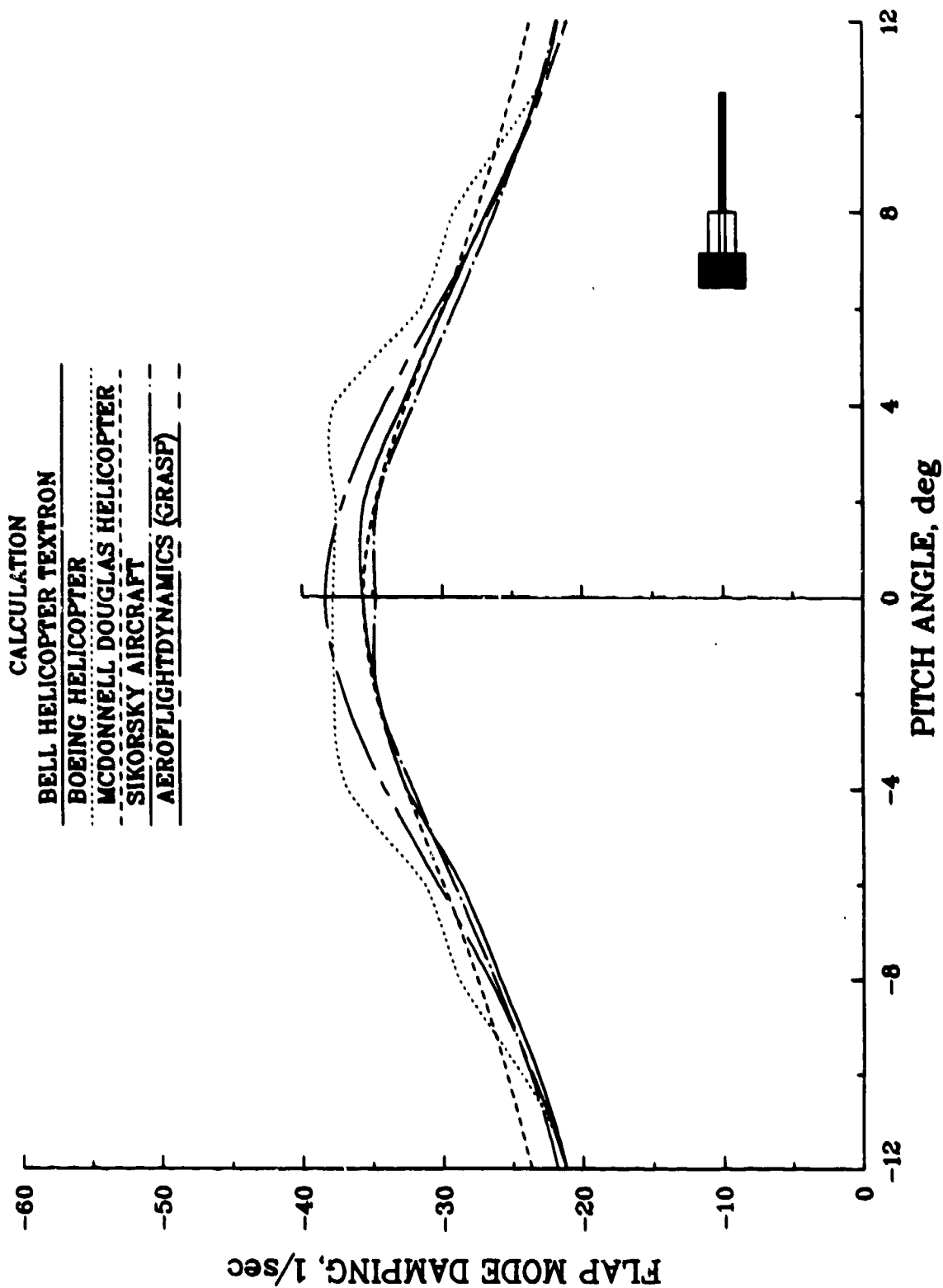


## References

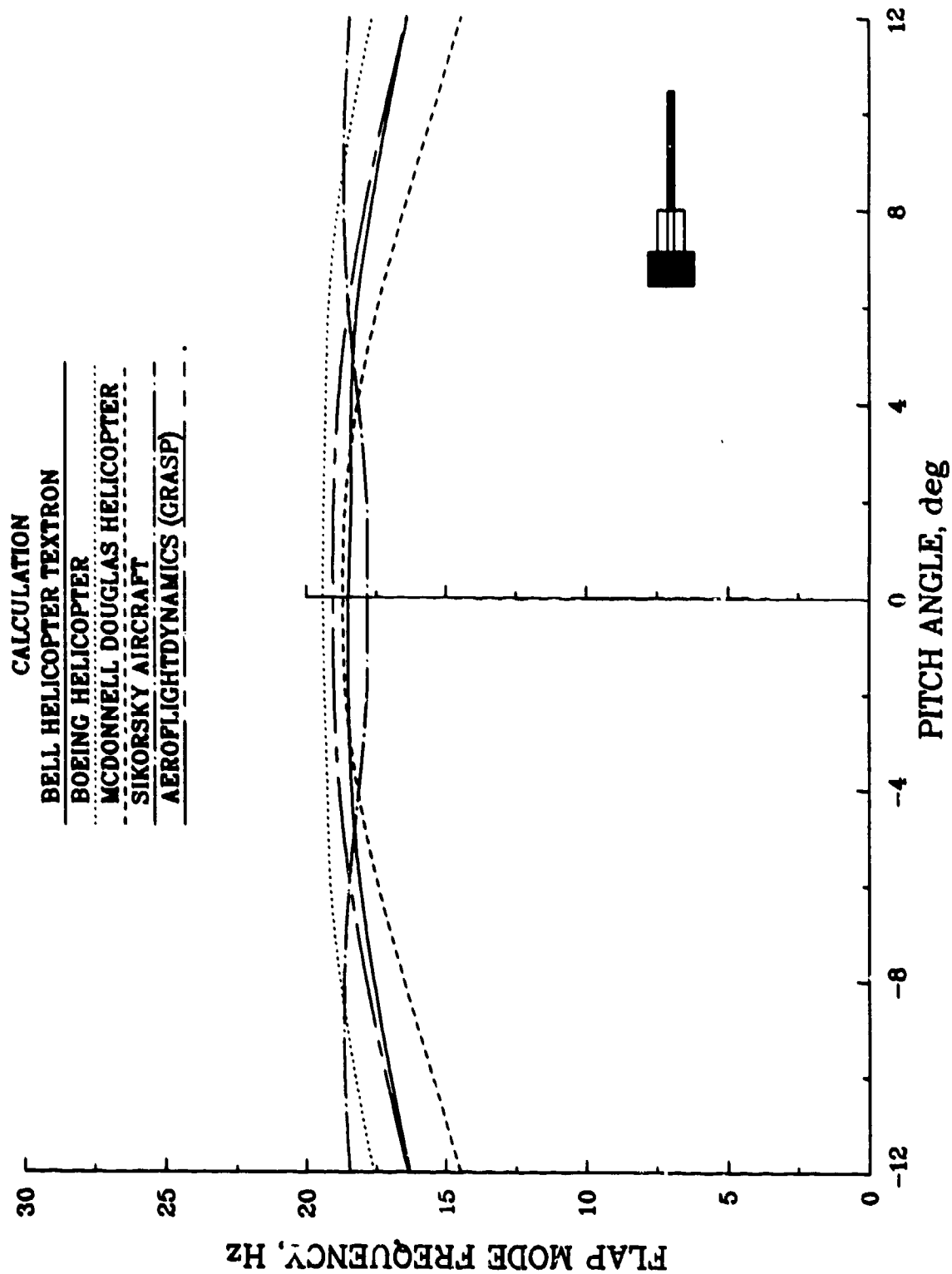
1. Michael J. McNulty and William G. Bousman (eds.), "Integrated Technology Rotor Methodology Assessment Workshop," NASA CP-10007, June 1983.
2. A. V. Srinivasan, D. G. Cutts, and H. T. Shu, "An Experimental Investigation of a Torsionally Soft Rotor in Vacuum," NASA CR-177418, July 1986.
3. William G. Bousman, "An Experimental Investigation of the Effects of Aeroelastic Couplings on Aeromechanical Stability of a Hingeless Rotor Helicopter," *Journal of the American Helicopter Society*, Vol. 26, No. 1, Jan. 1981, pp. 45-54.
4. W. Johnson, "Influence of Unsteady Aerodynamics on Hingeless Rotor Ground Resonance," *J. Aircraft*, Vol. 29, No. 8, Aug. 1982, pp. 668-673.

**APPENDIX**  
**ROTOR CONFIGURATION ANALYSIS DATA**

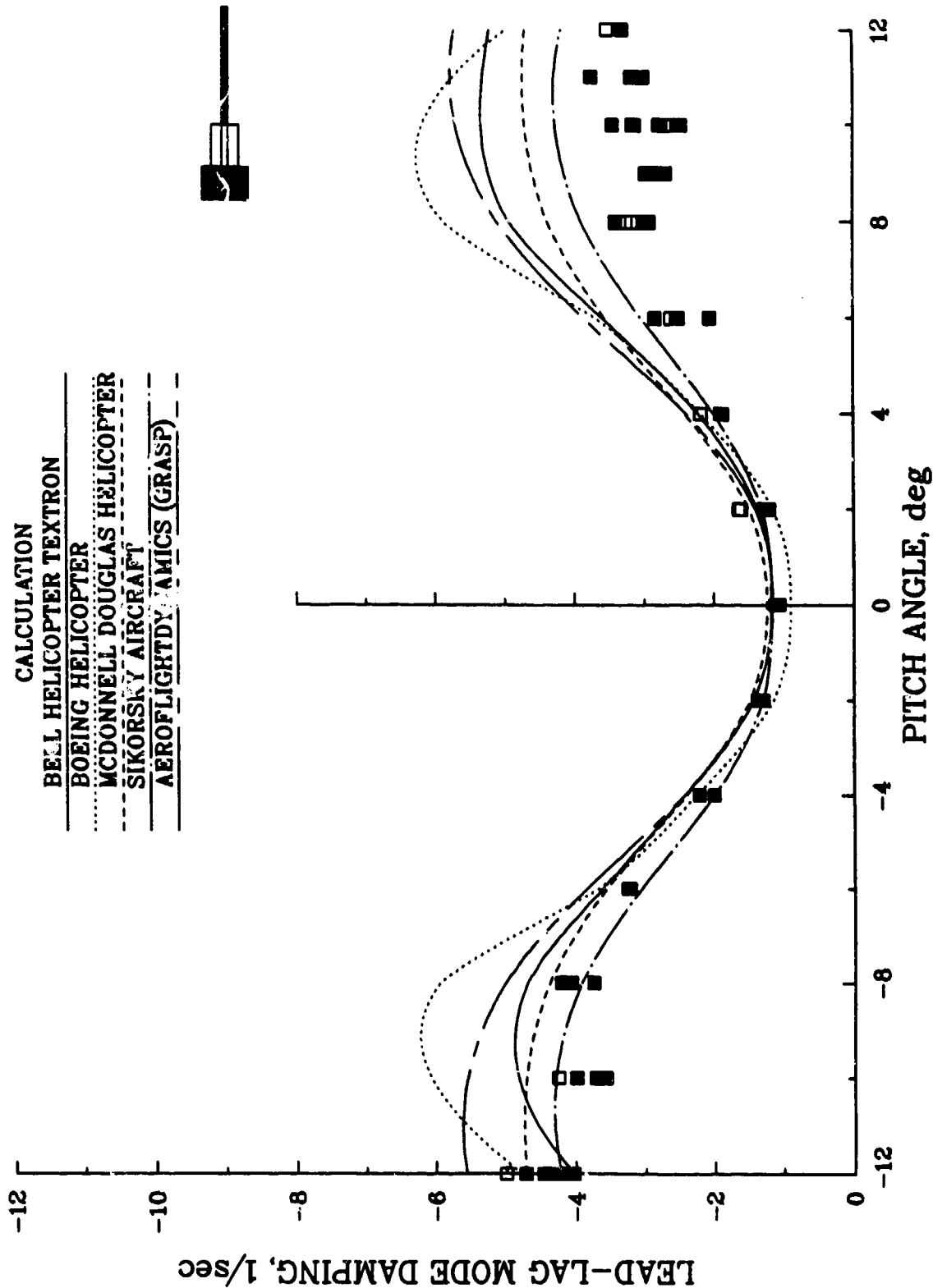
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 CASE 2 - TORSIONALLY SOFT ROTOR



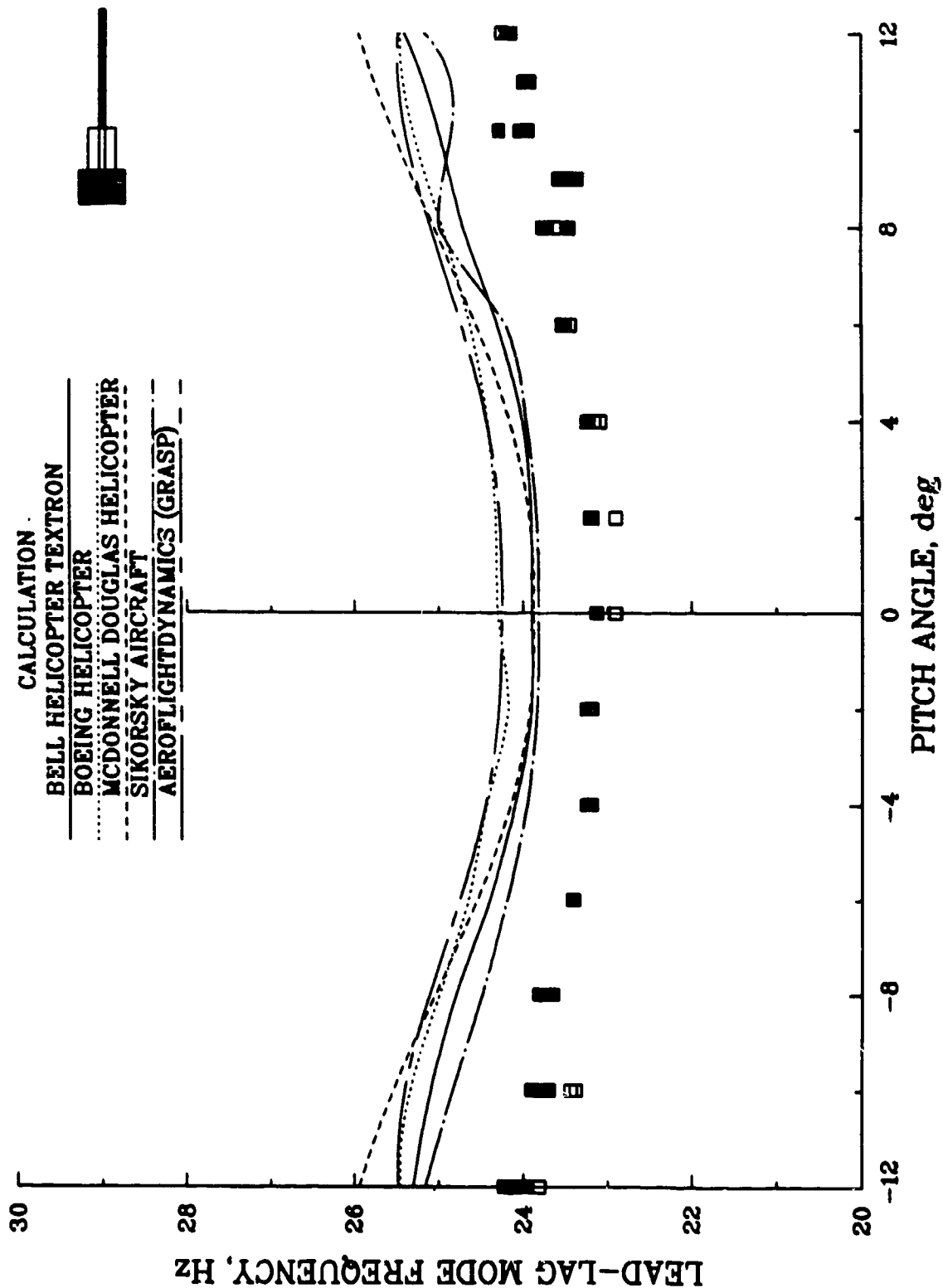
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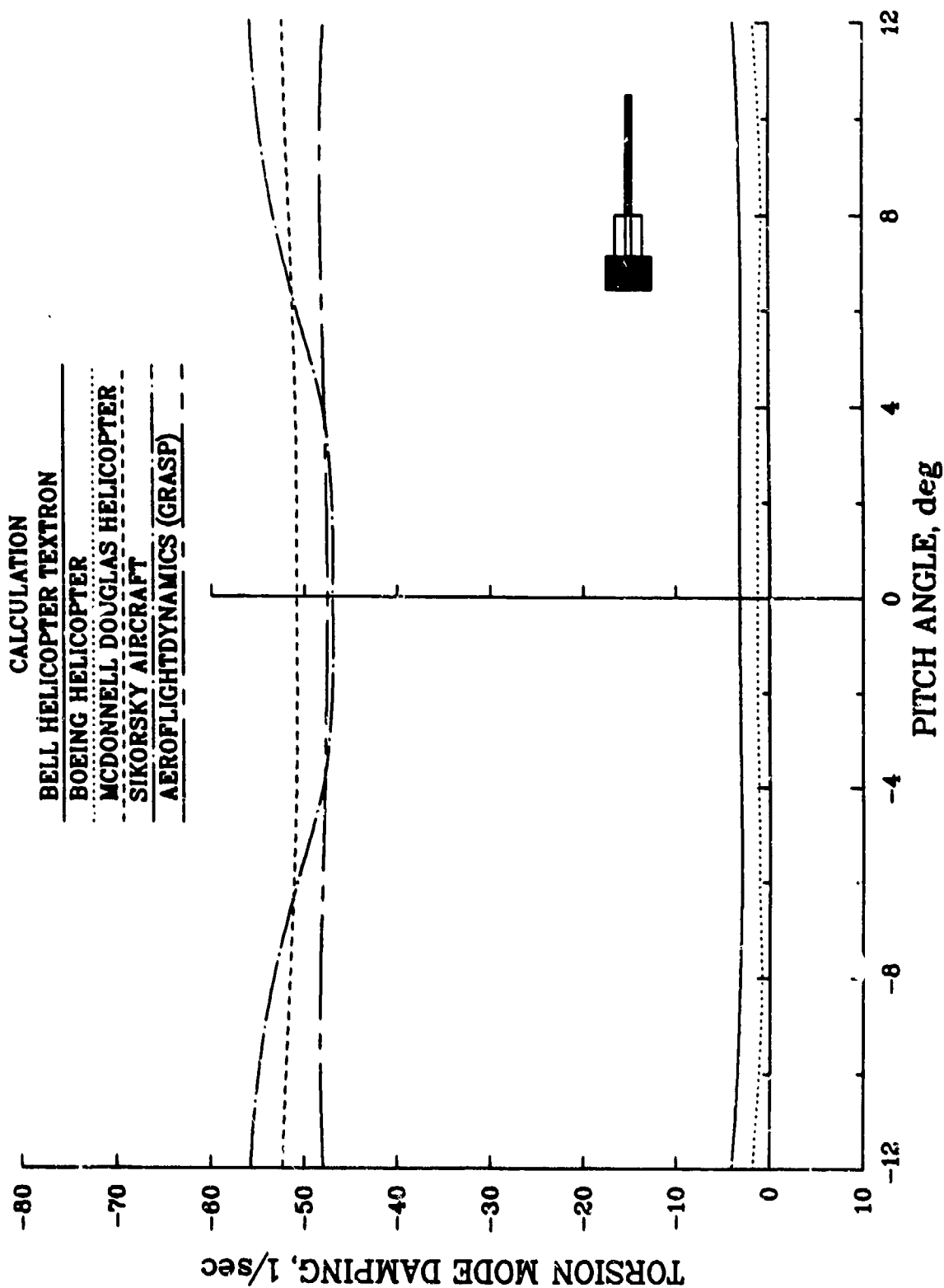
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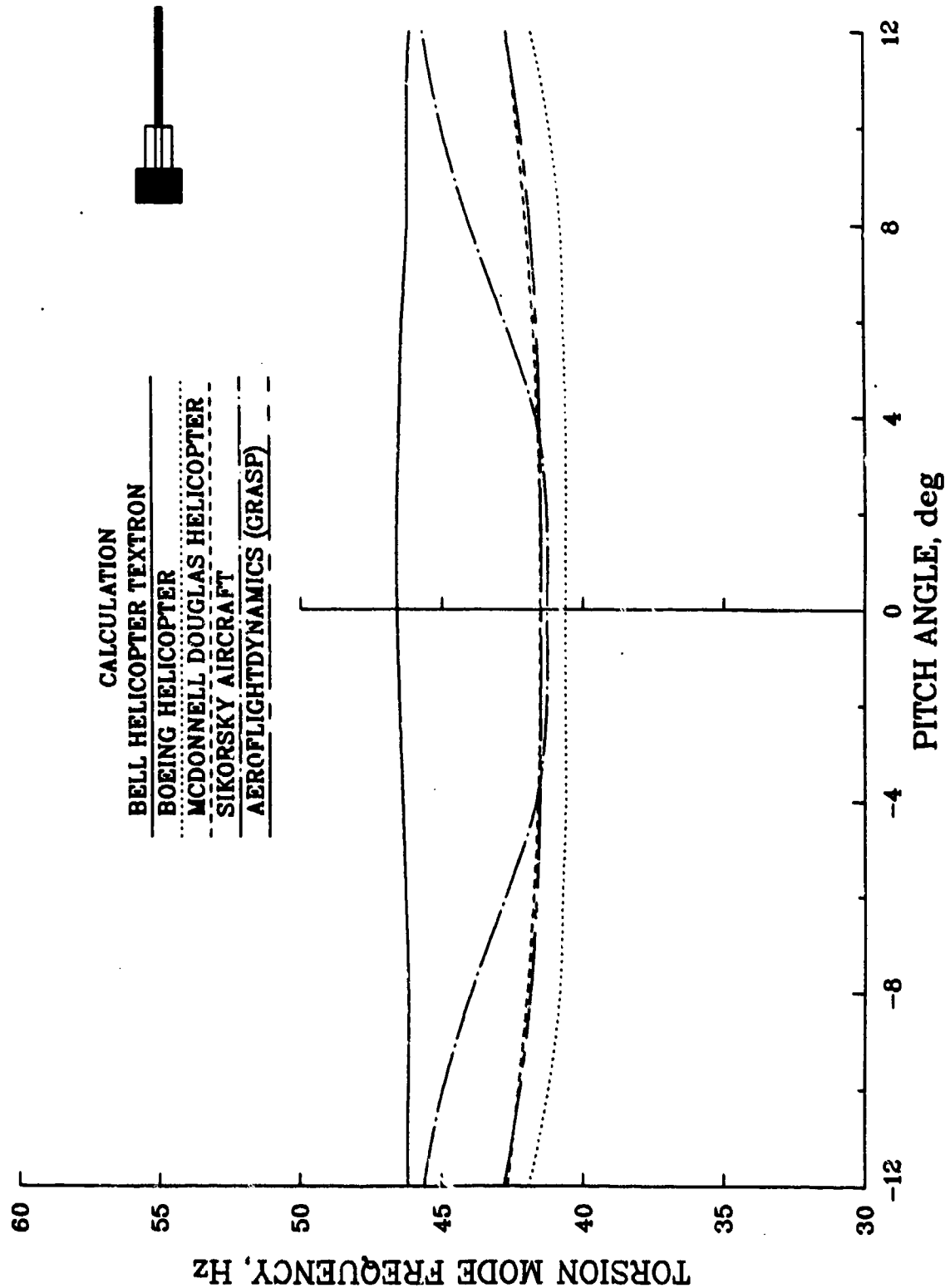
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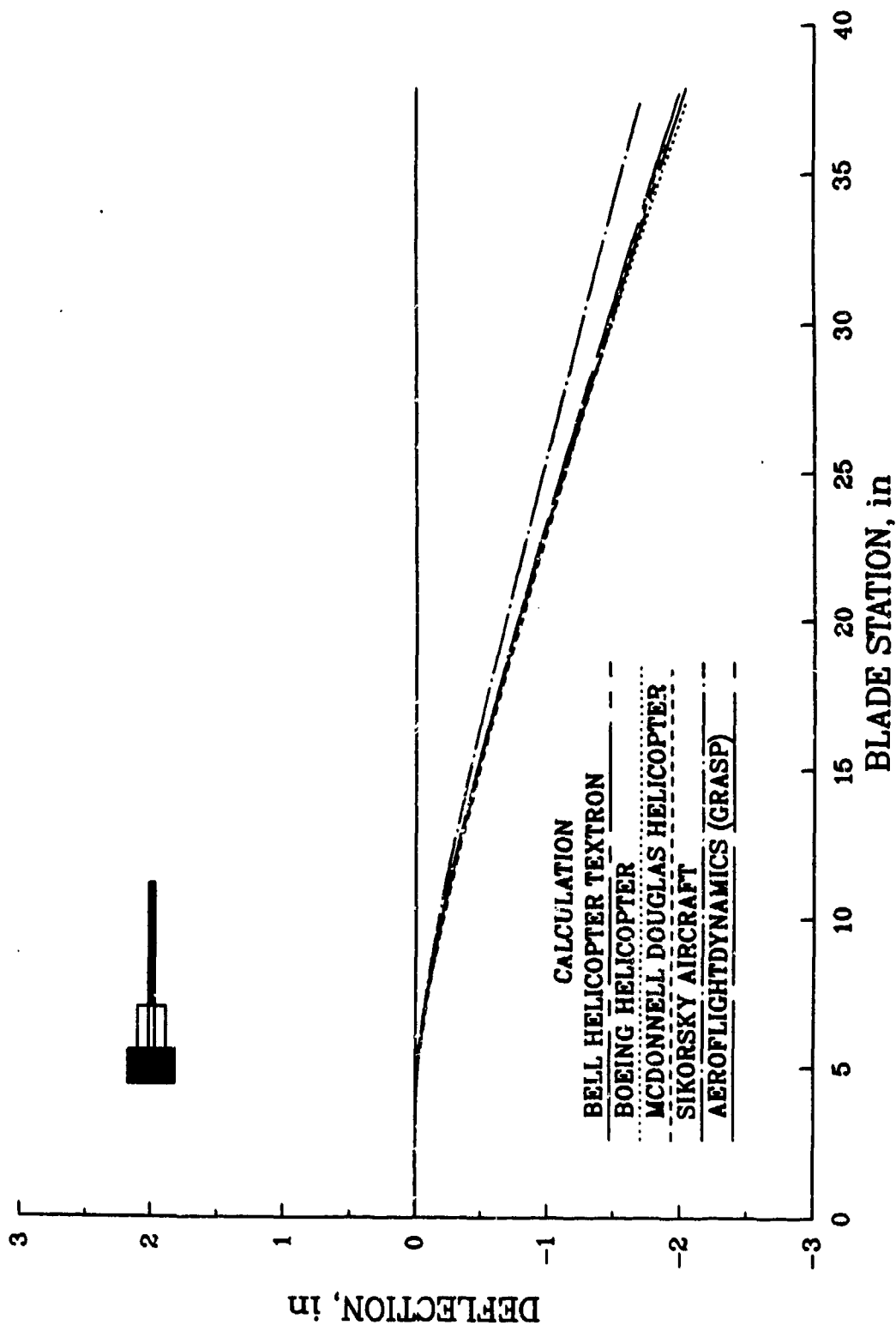


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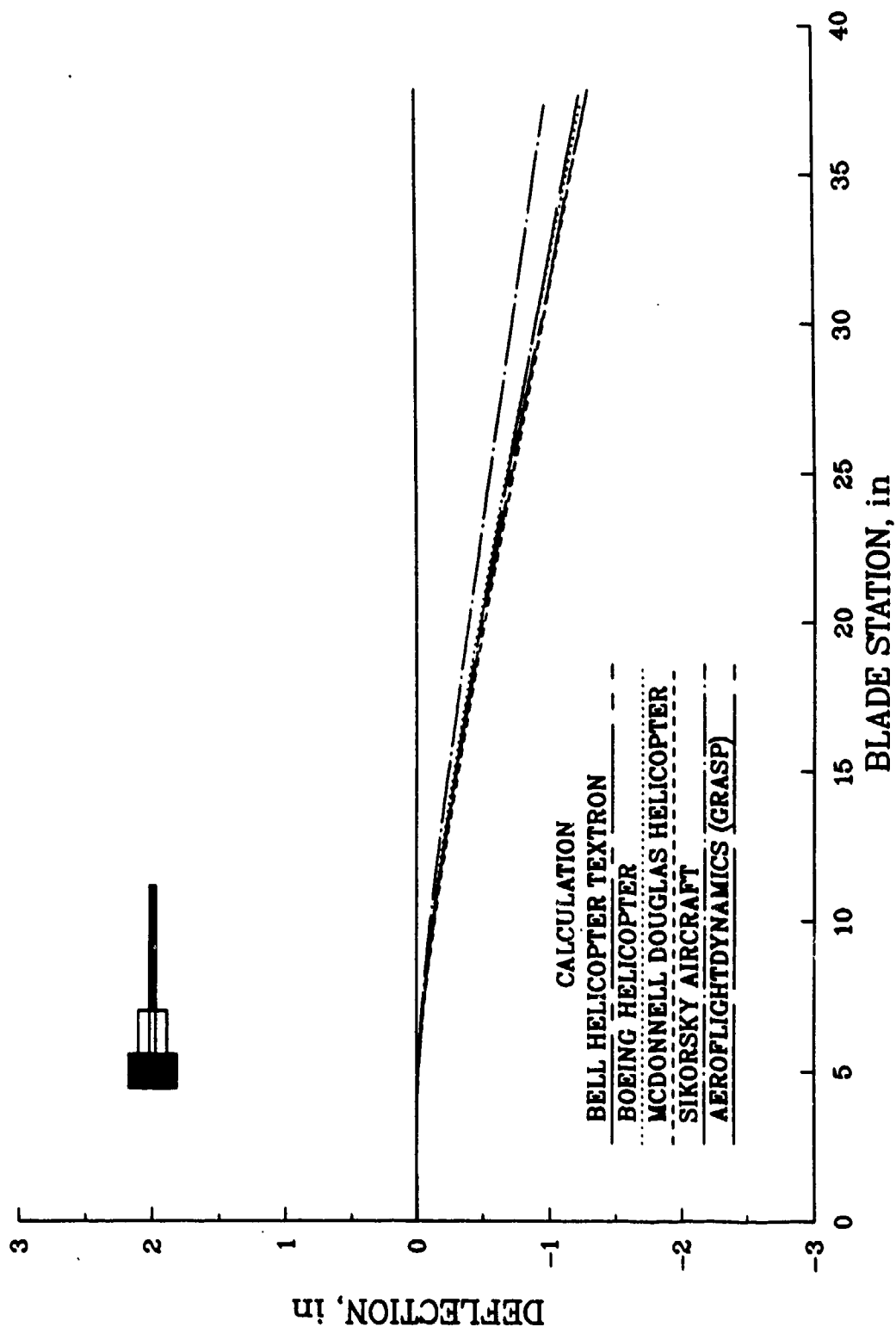


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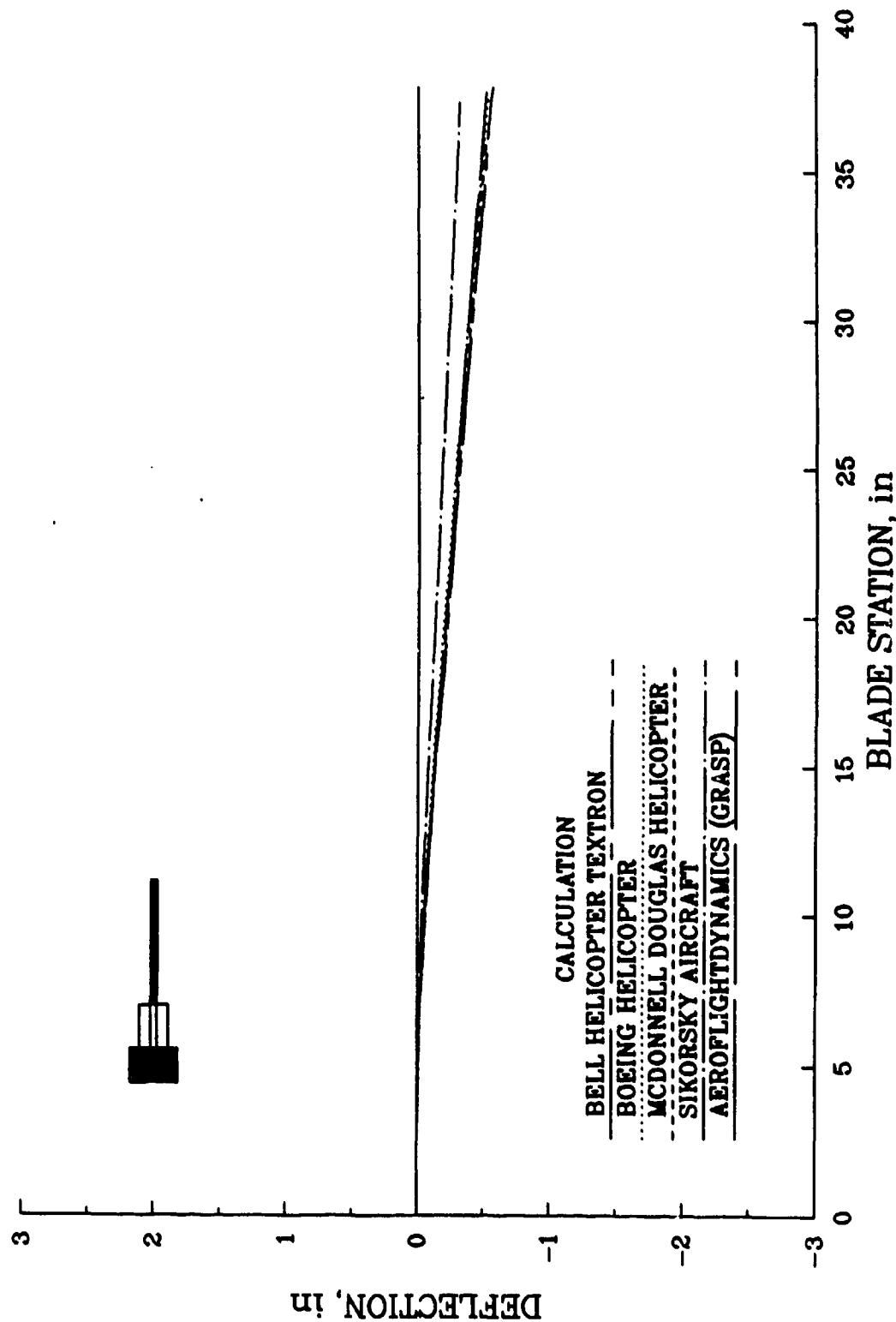


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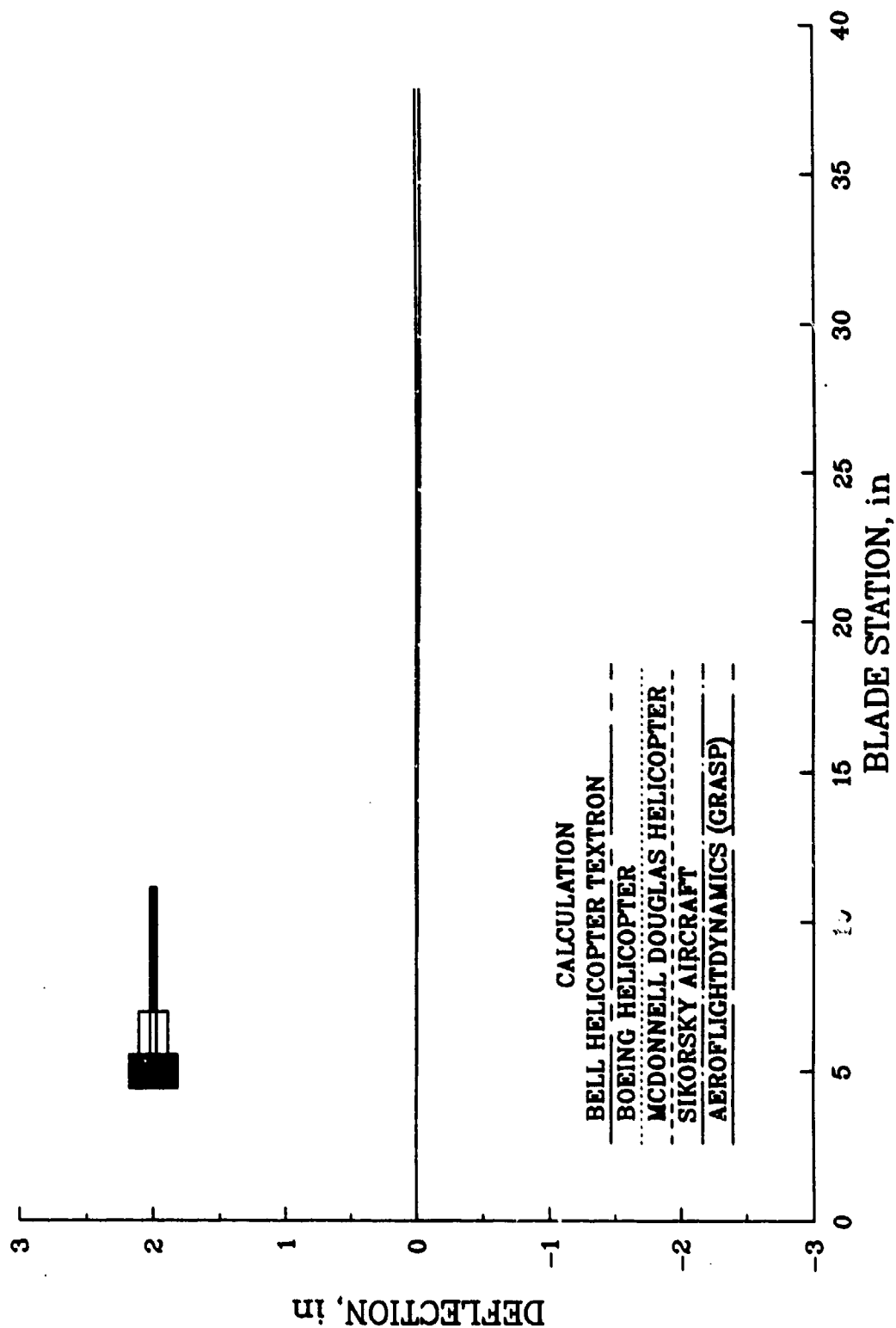


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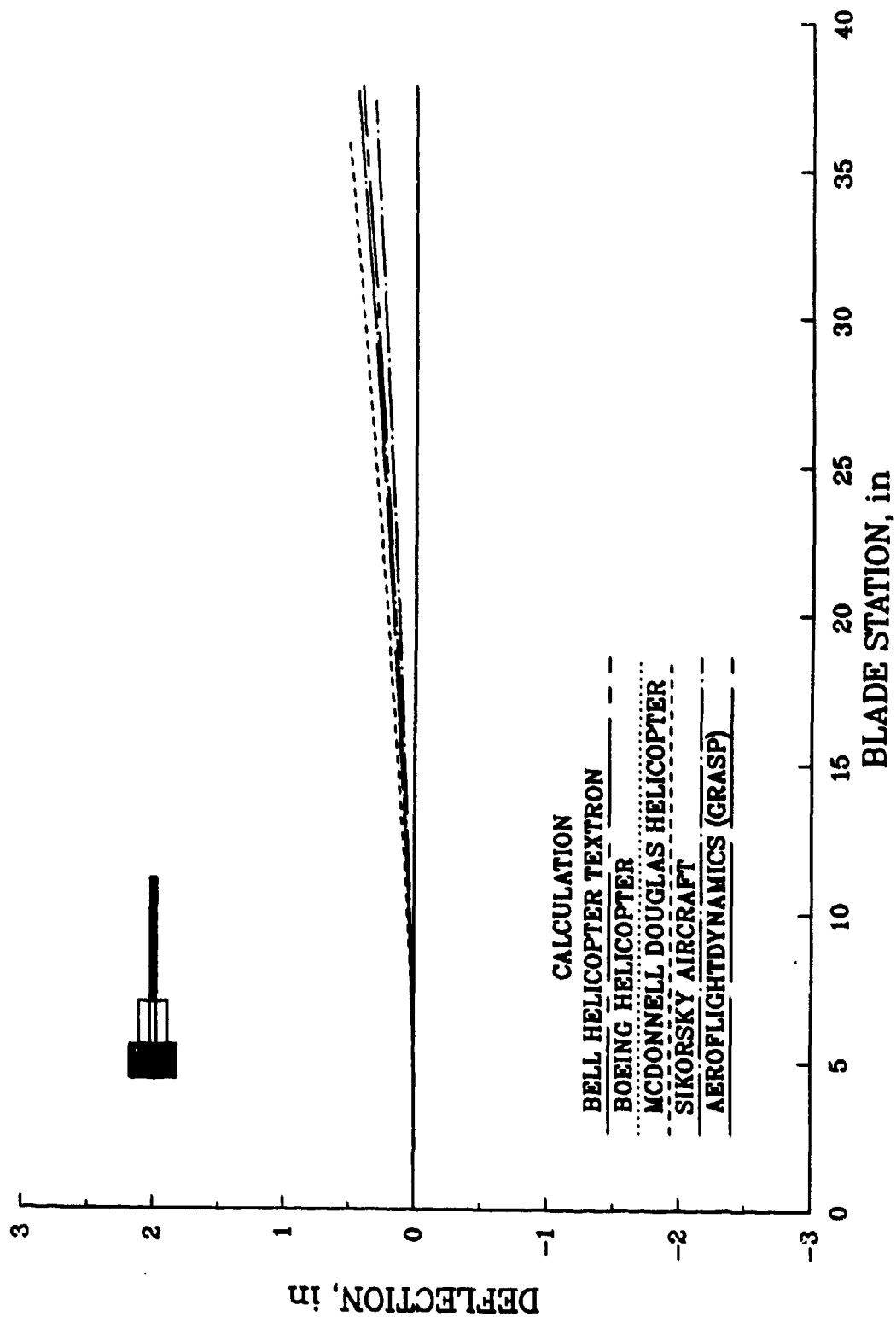


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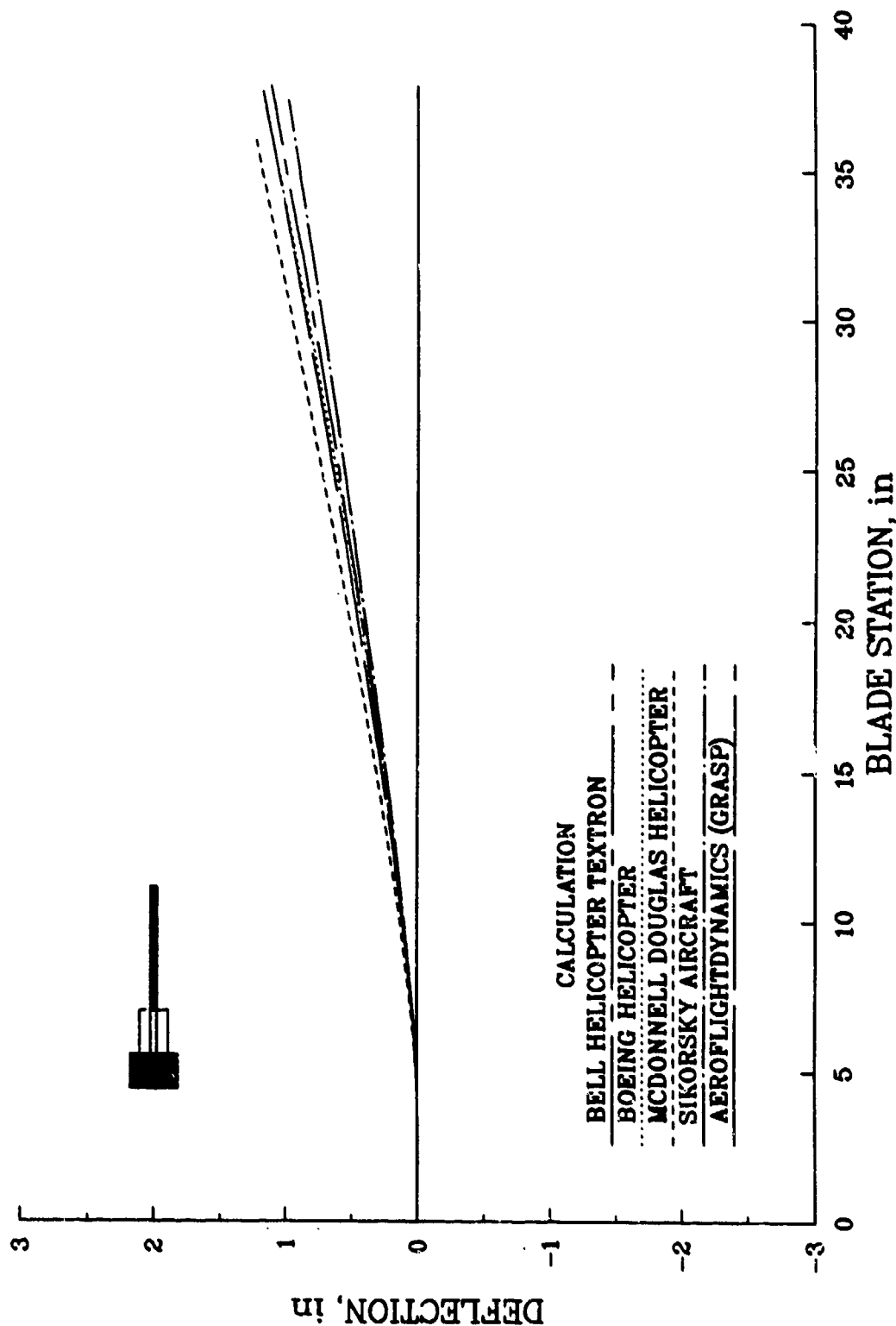
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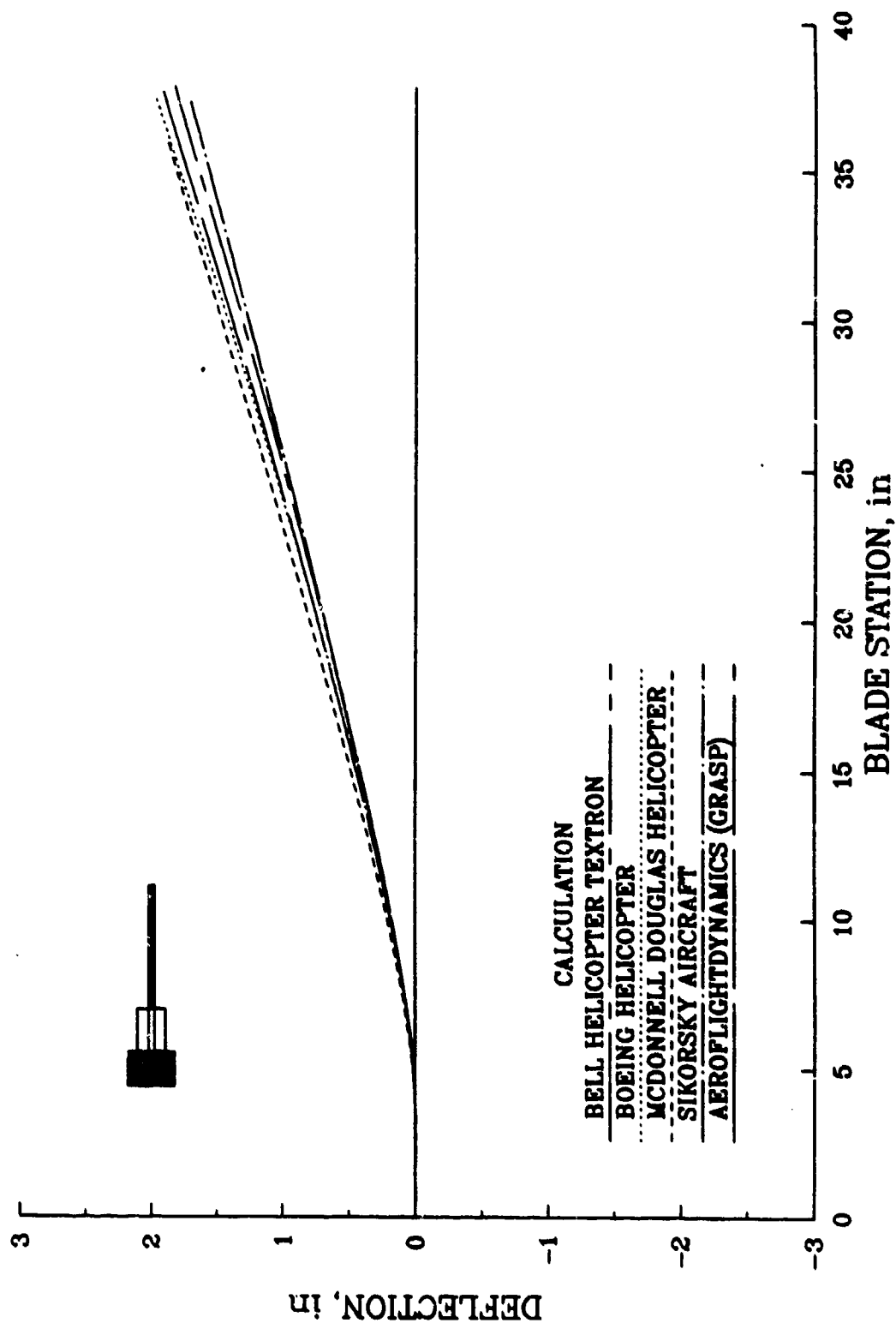
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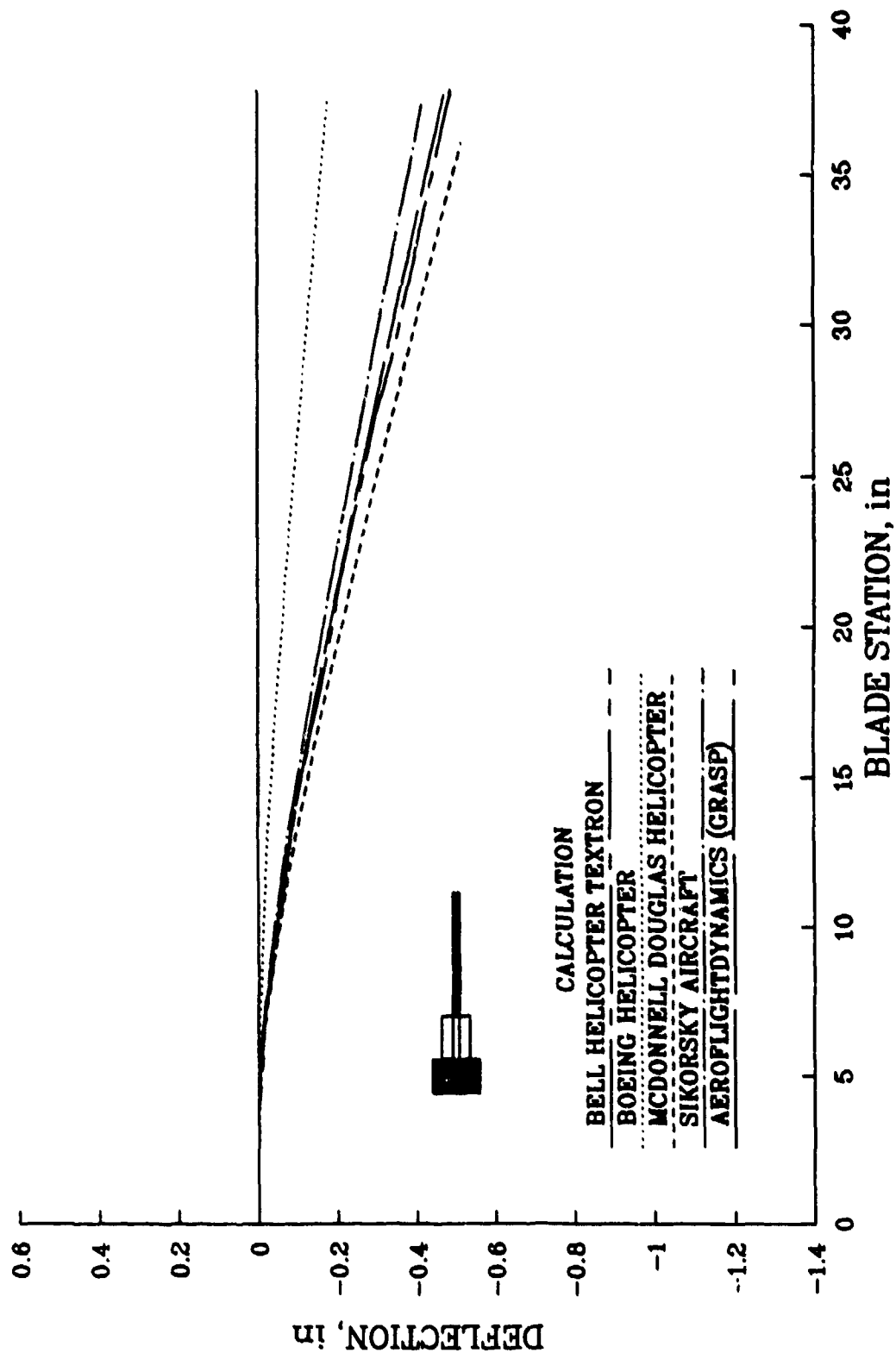
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 CASE 2 - TORSIONALLY SOFT ROTOR  
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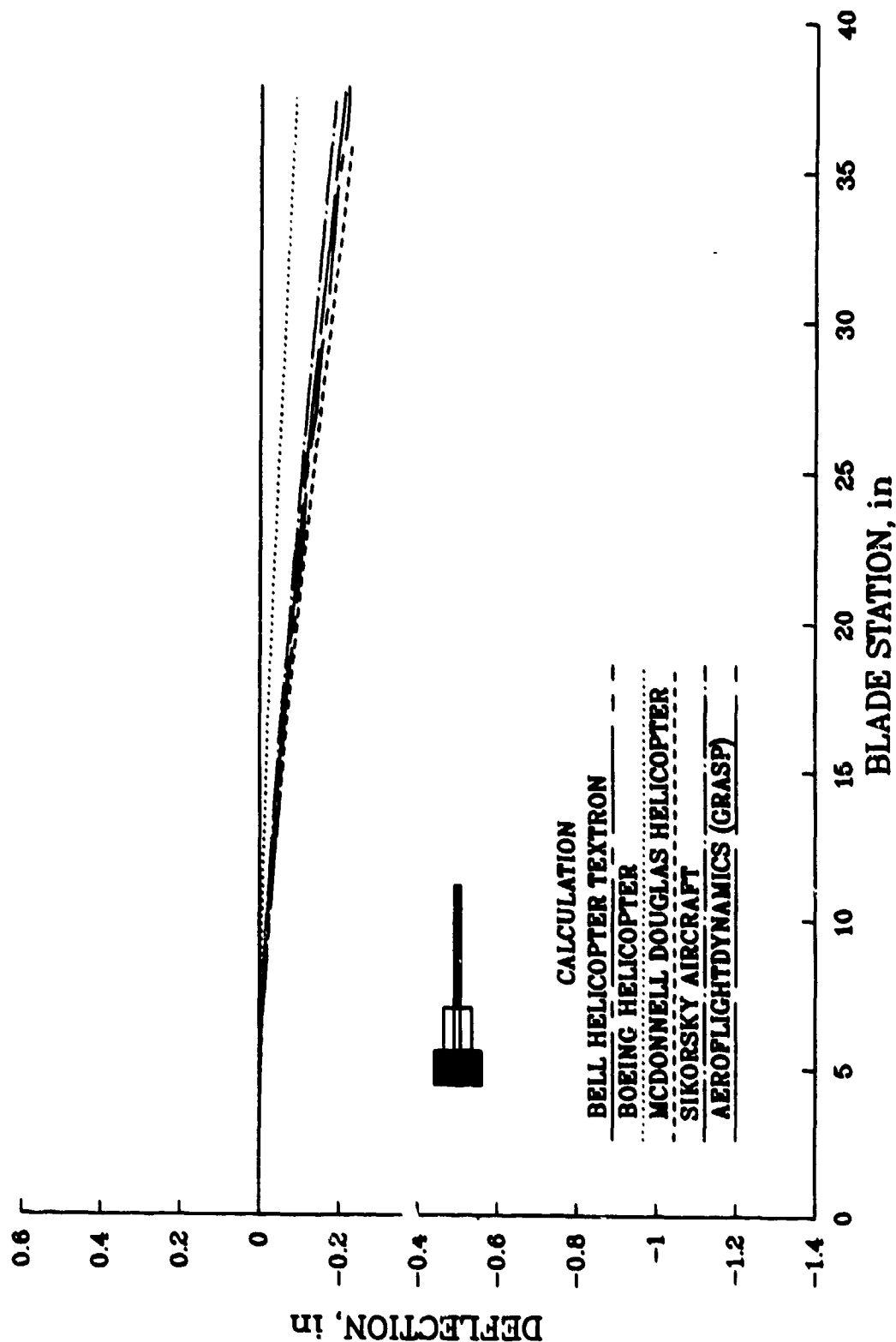


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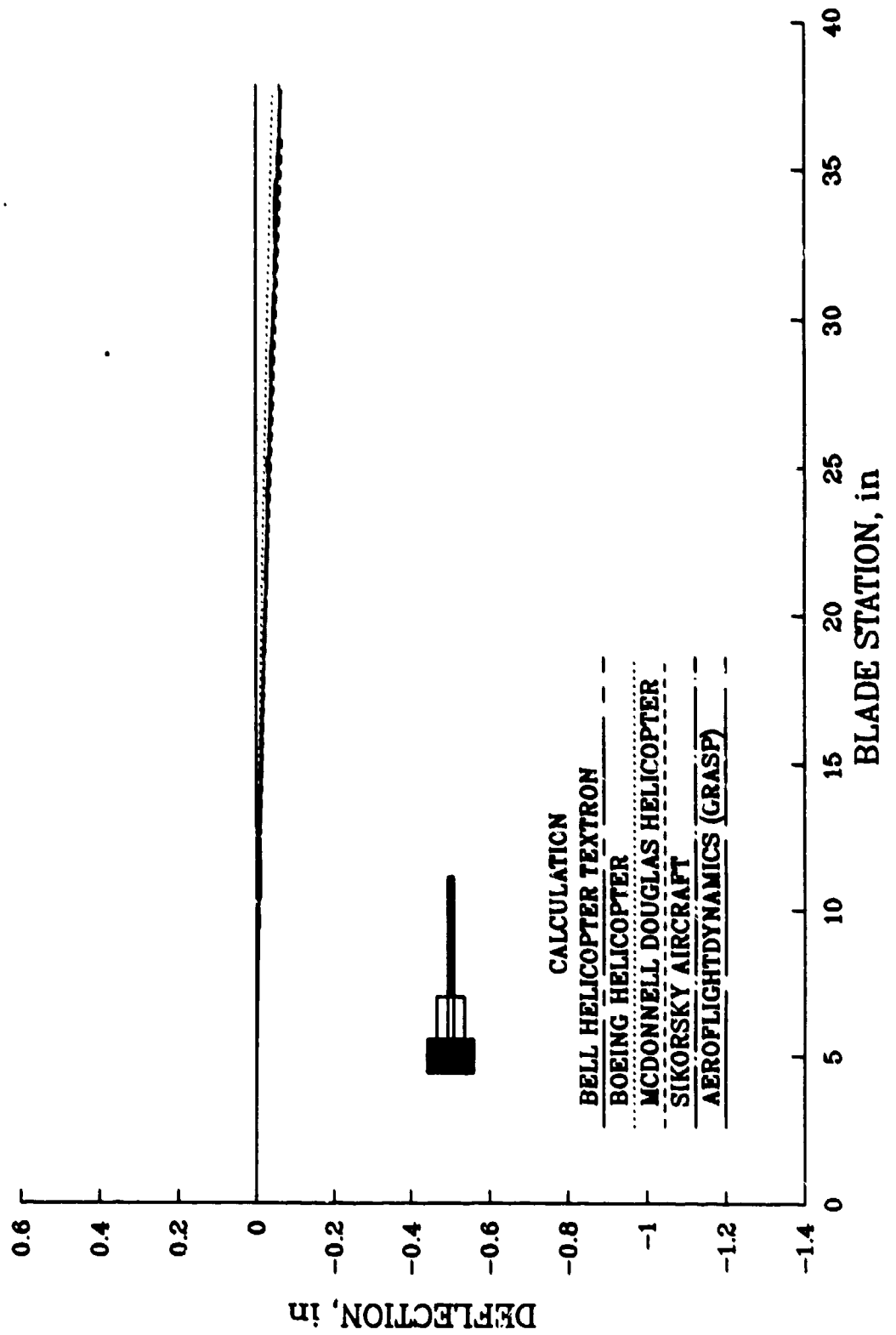




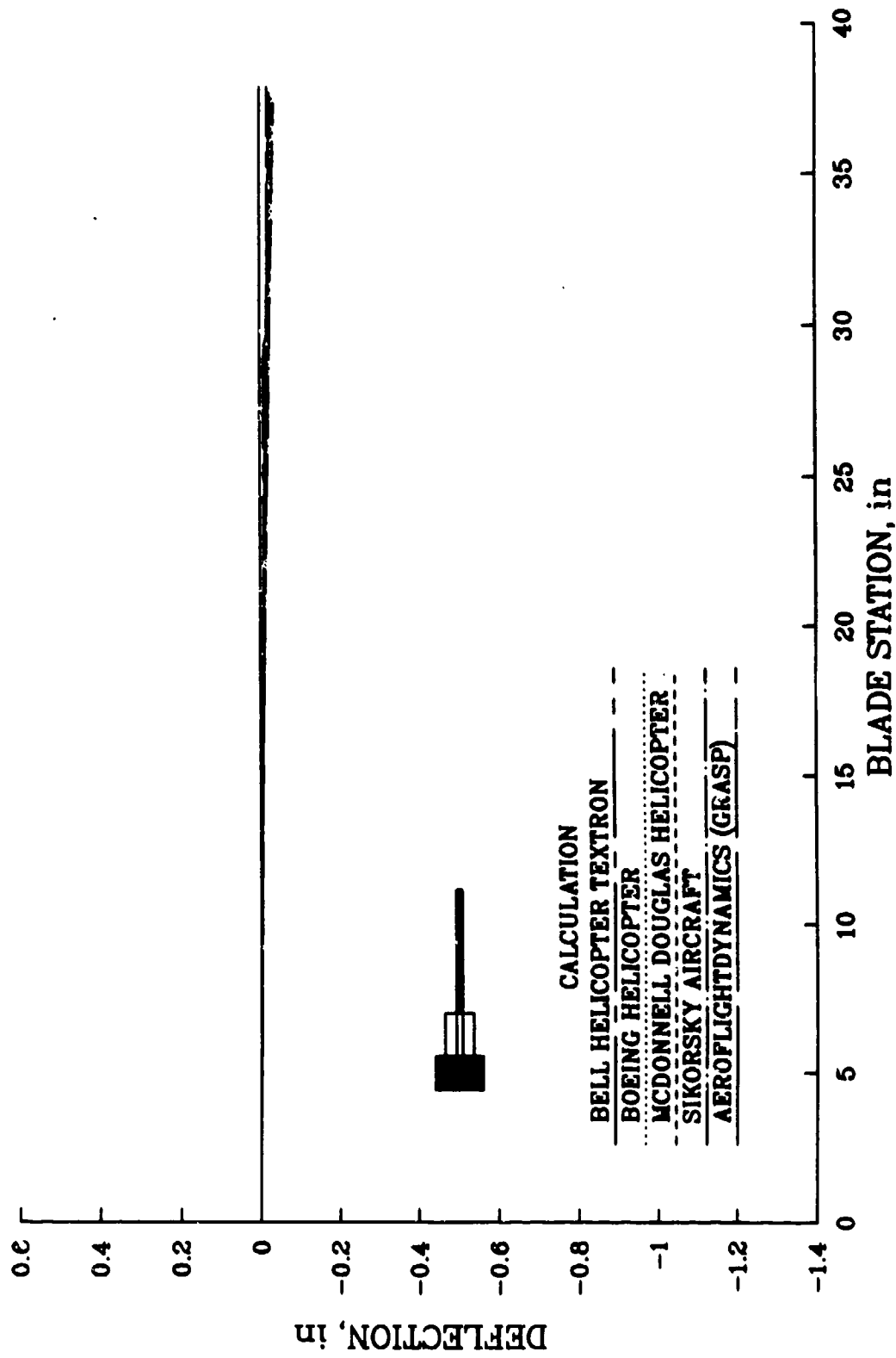
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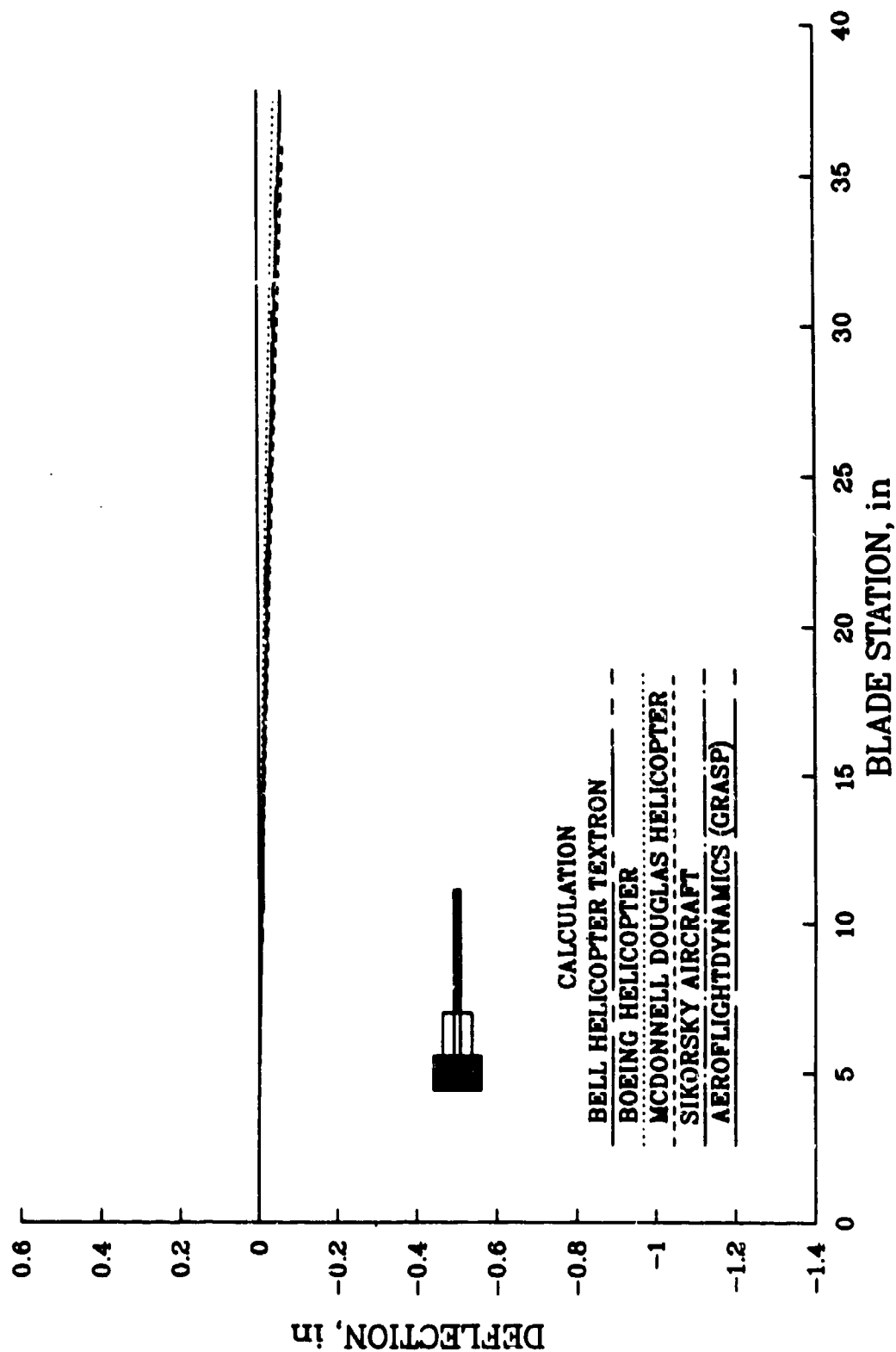
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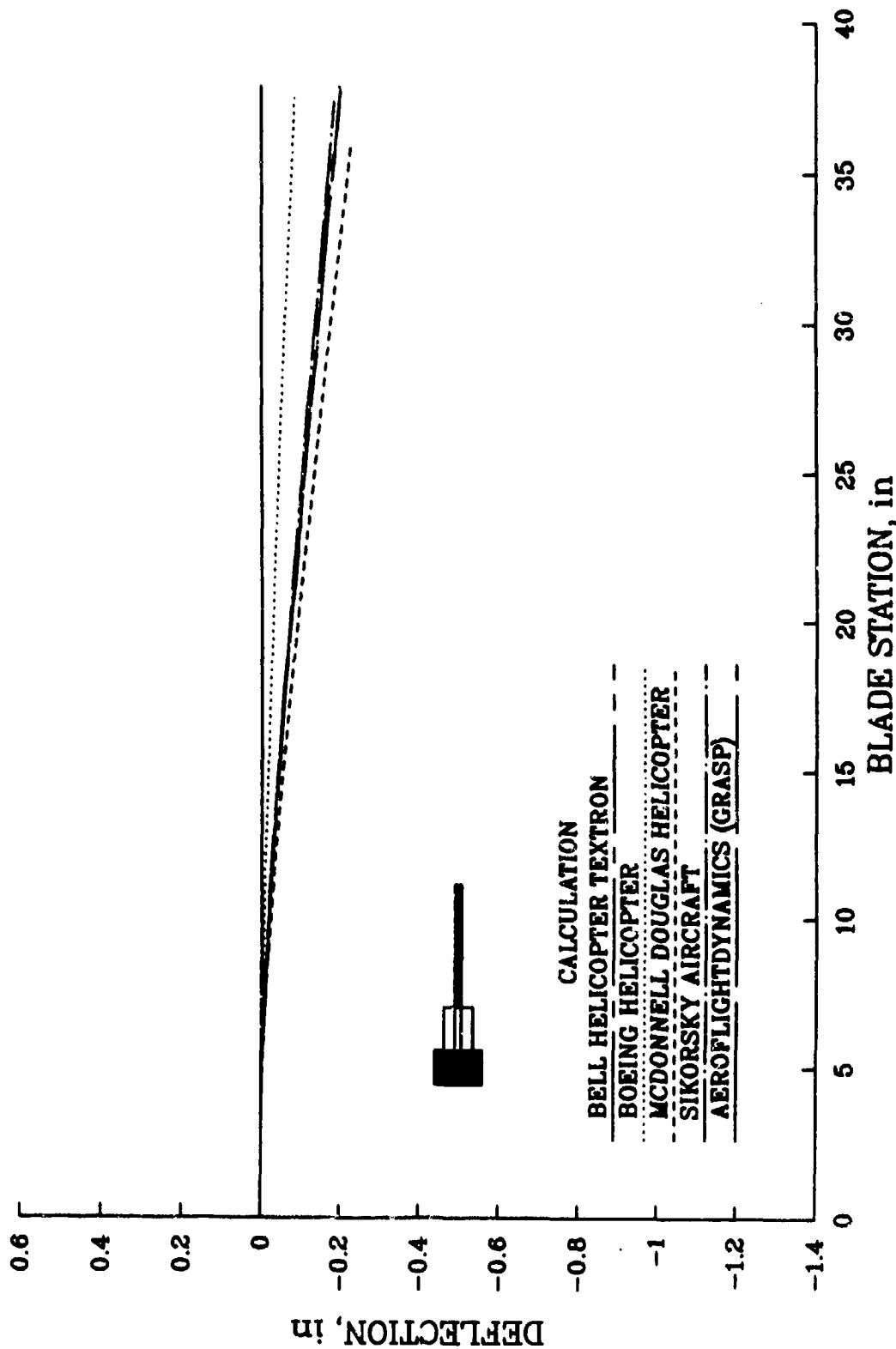
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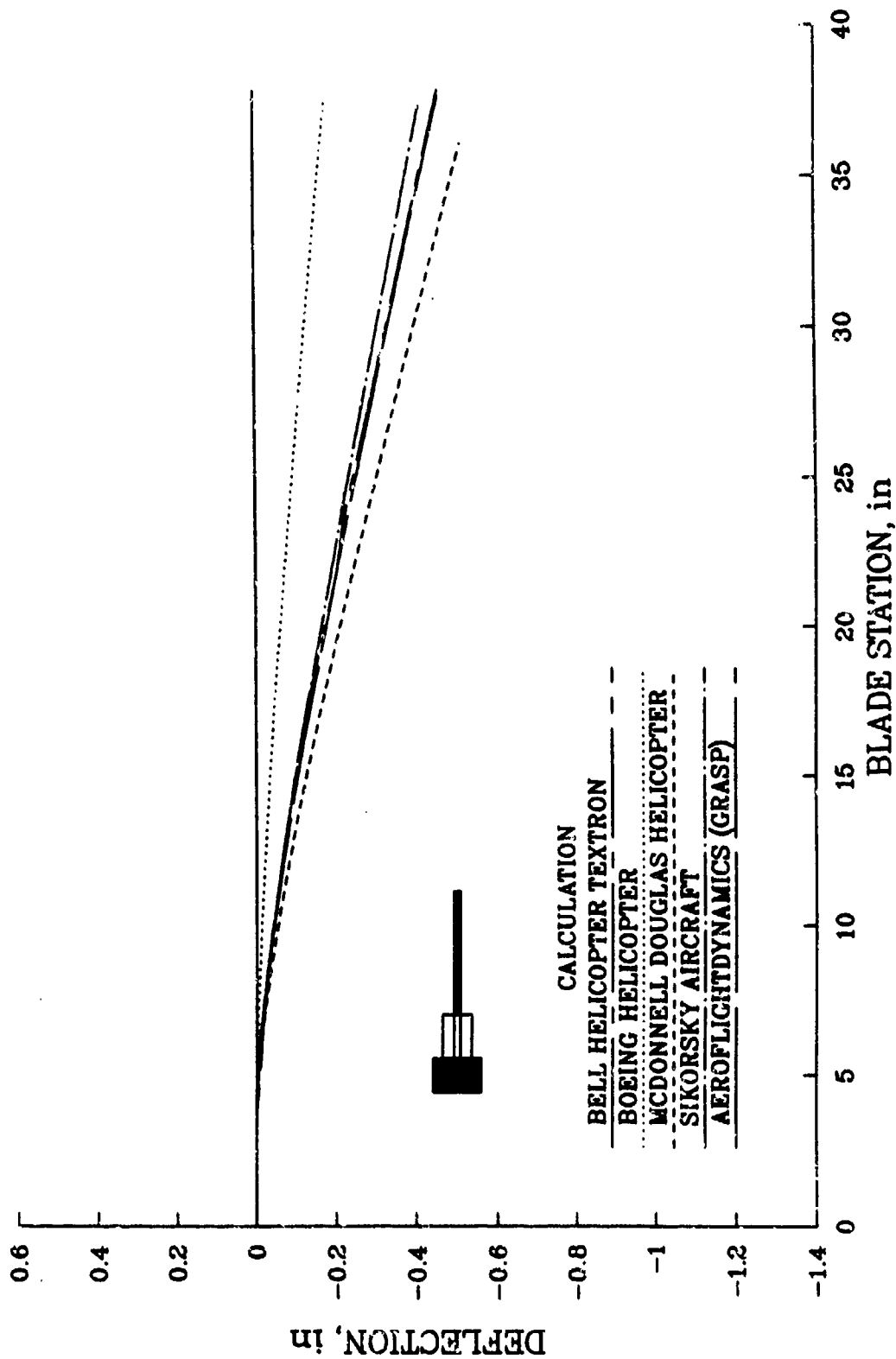
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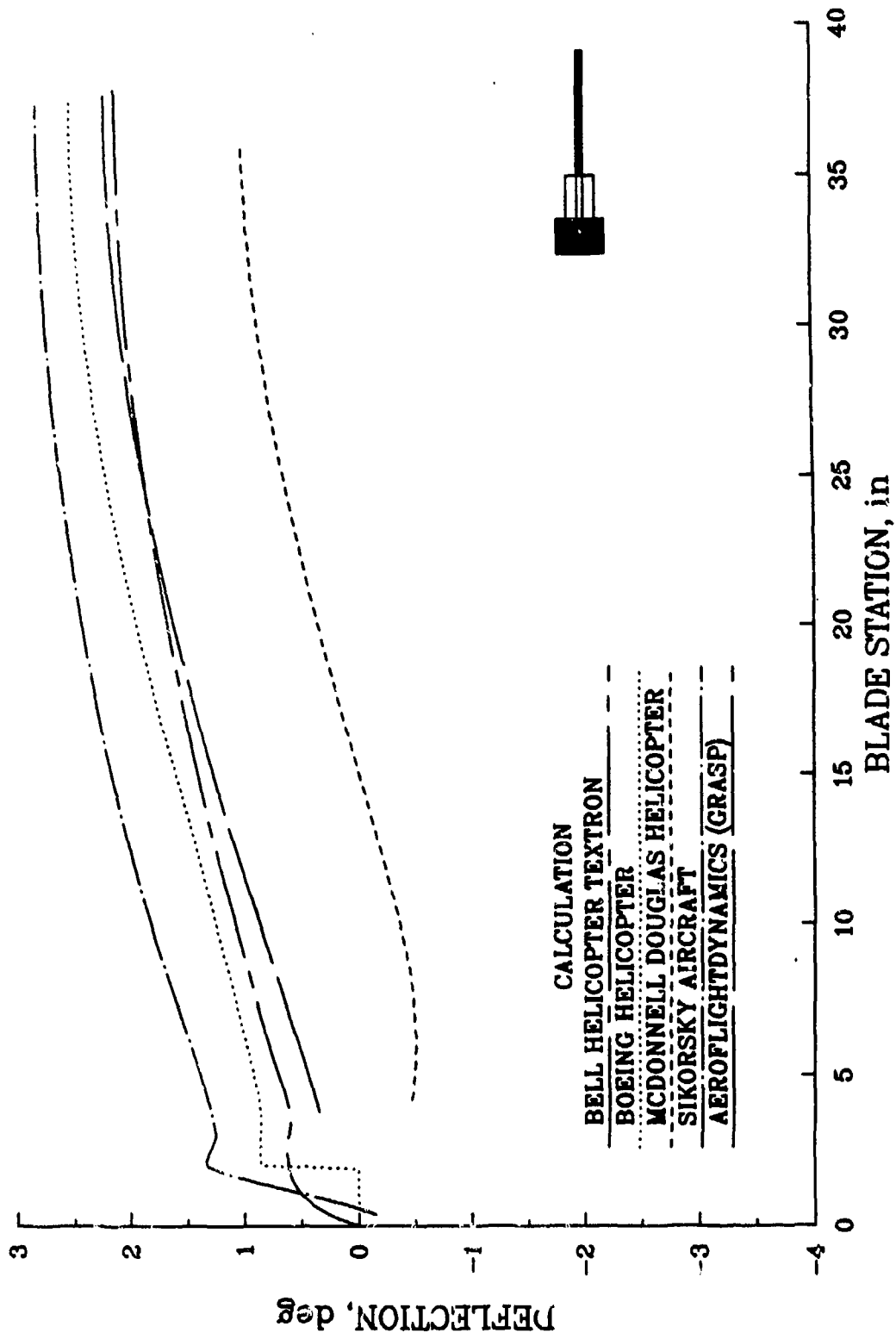
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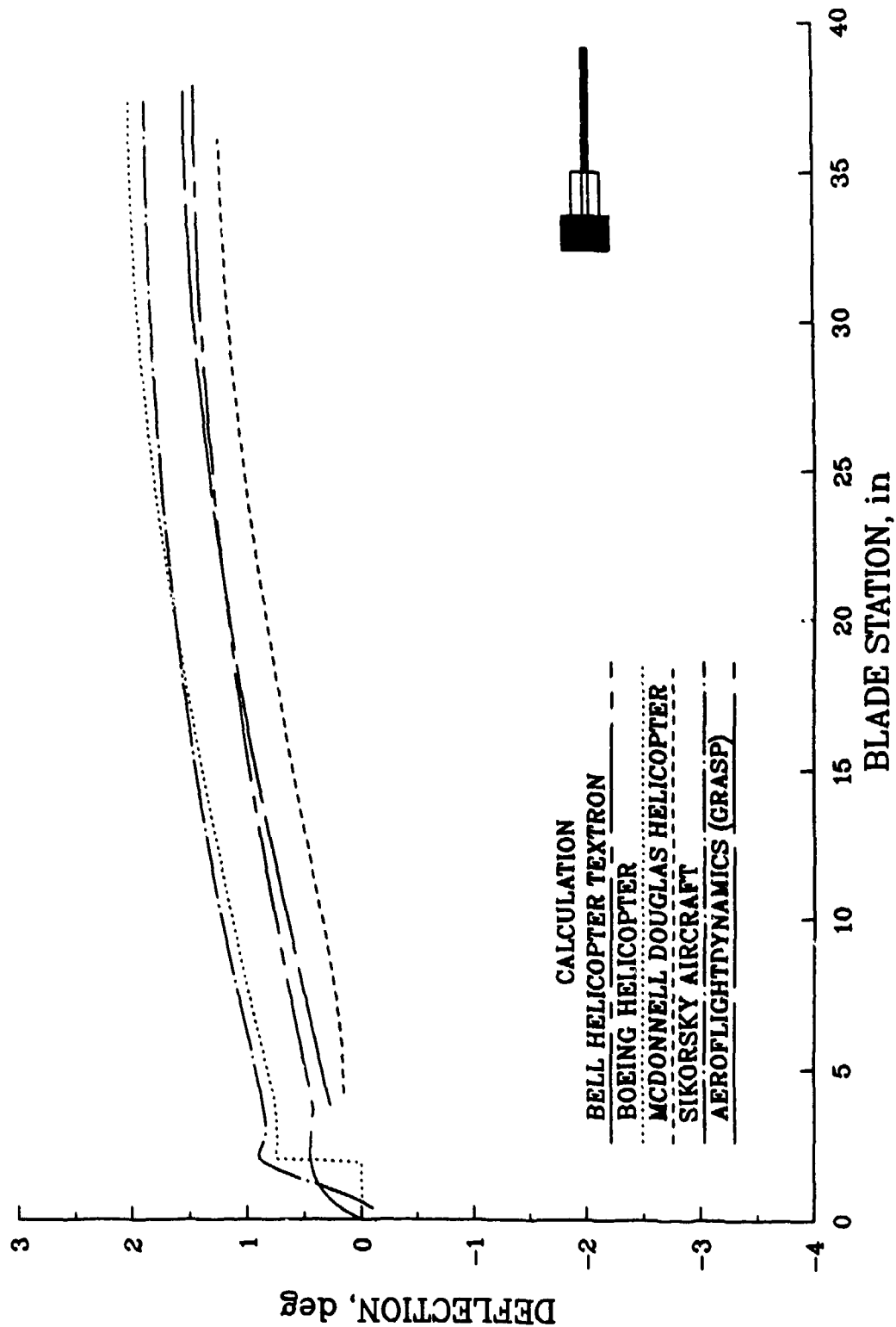
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**TORSION EQUILIBRIUM DEFLECTION - TASK 86d**  
**NONLINEAR AERODYNAMIC COEFFICIENTS**  
**CASE 2 - TORSIONALLY SOFT ROTOR**  
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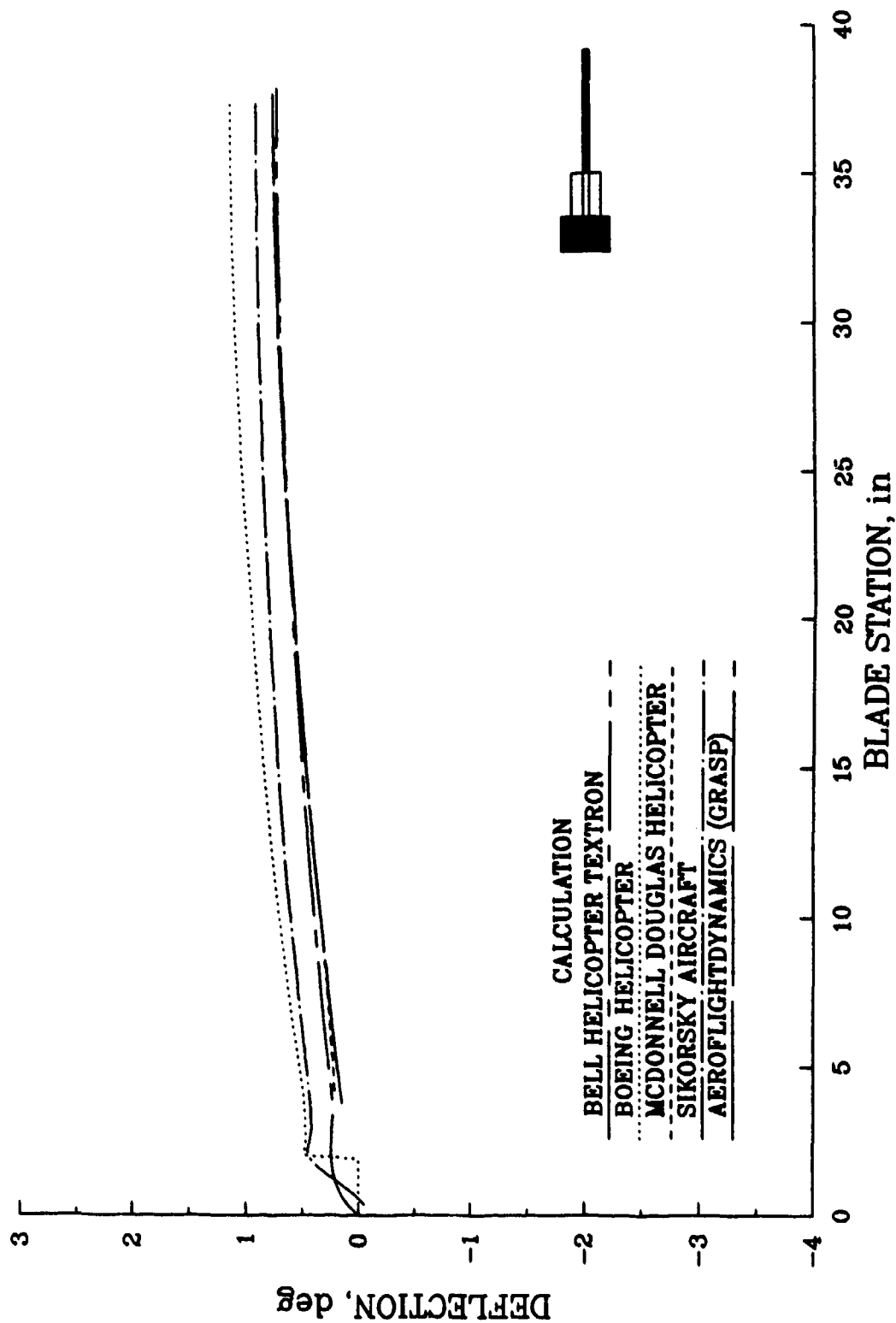


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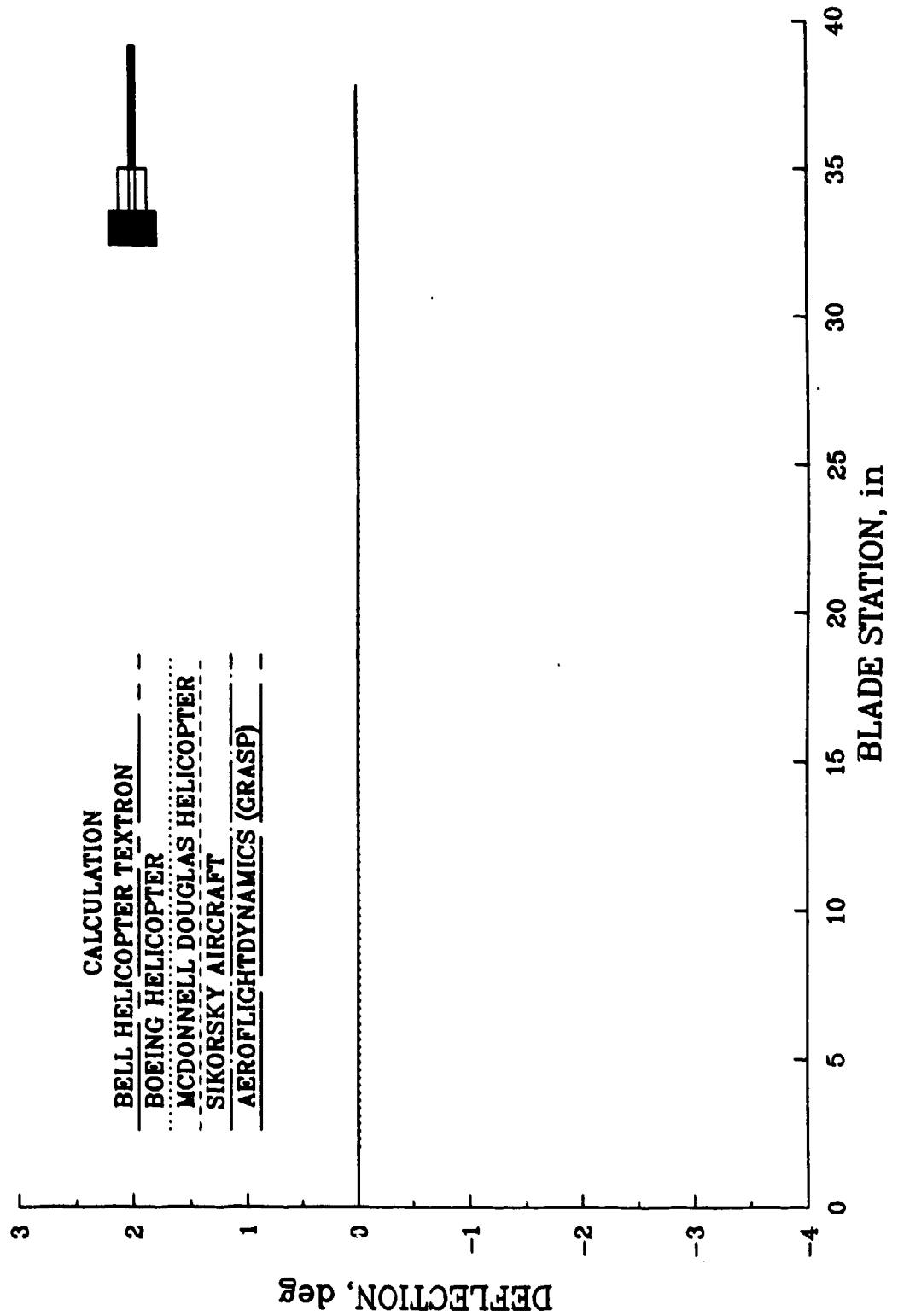
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TORSION EQUILIBRIUM DEFLECTION - TASK 86d  
 NONLINEAR AERODYNAMIC COEFFICIENTS

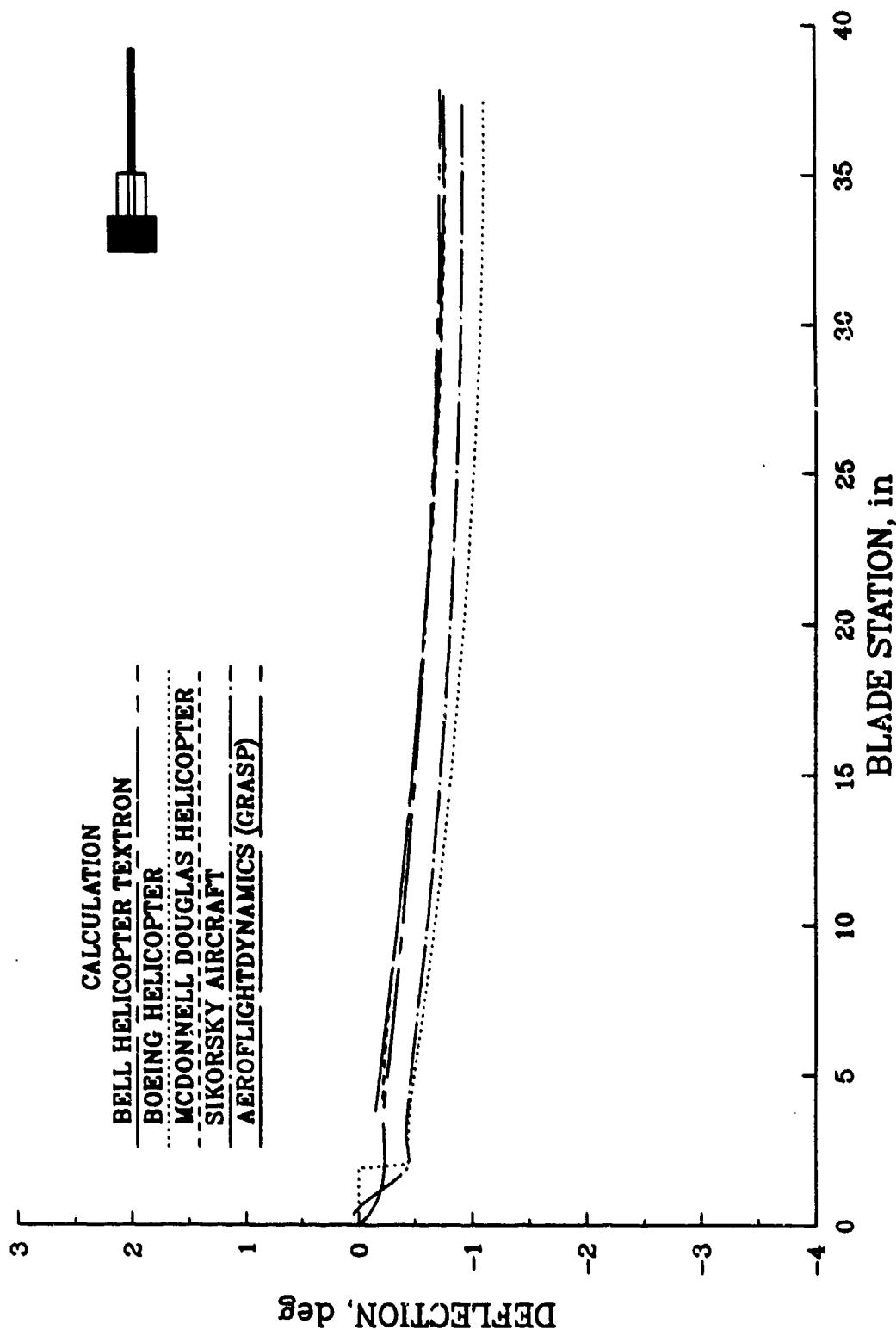
CASE 2 TORSIONALLY SOFT ROTOR

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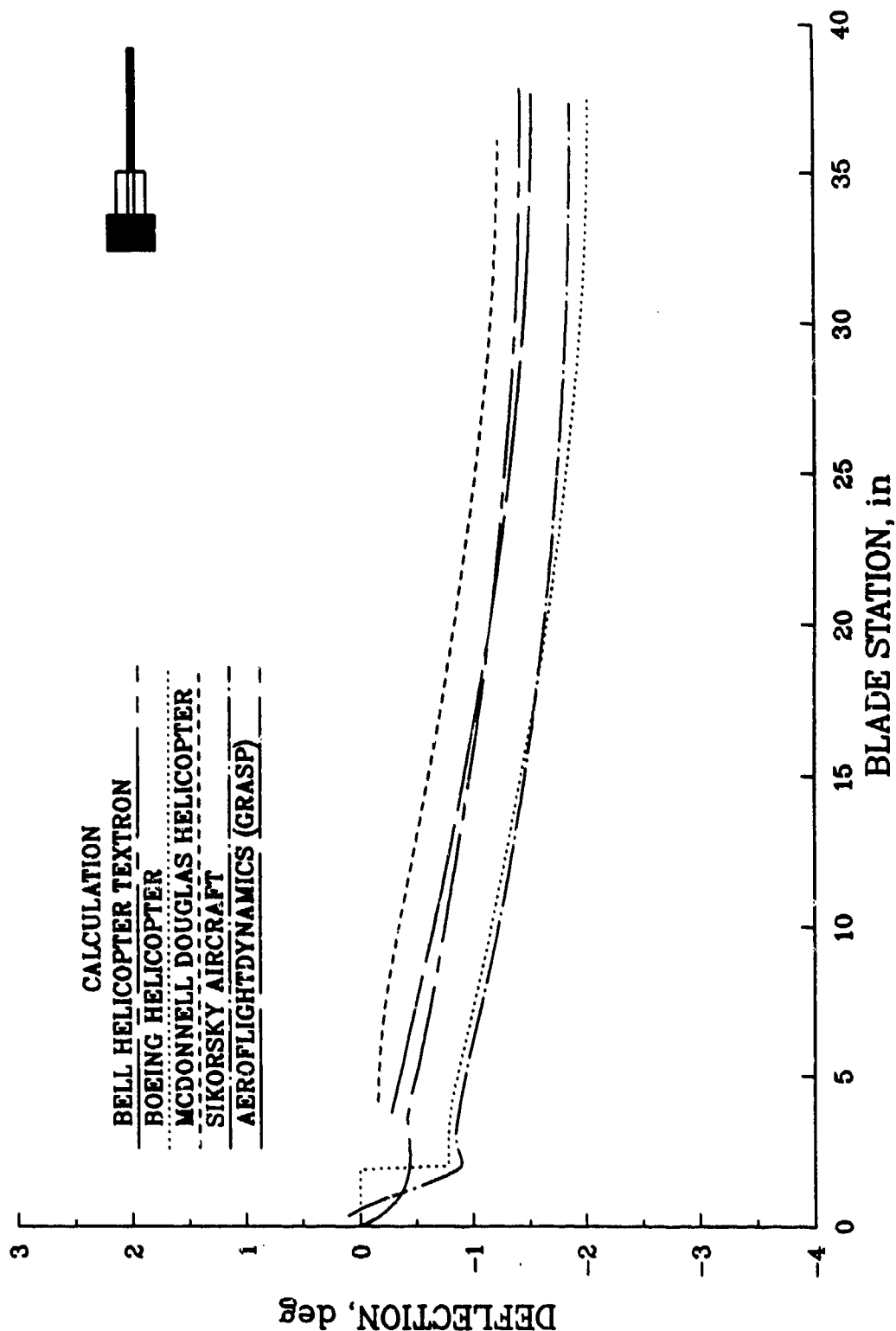


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 CASE 2 - TORSIONALLY SOFT ROTOR

PITCH ANGLE = 4 deg



TORSION EQUILIBRIUM DEFLECTION - TASK 86d  
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 CASE 2 - TORSIONALLY SOFT ROTOR  
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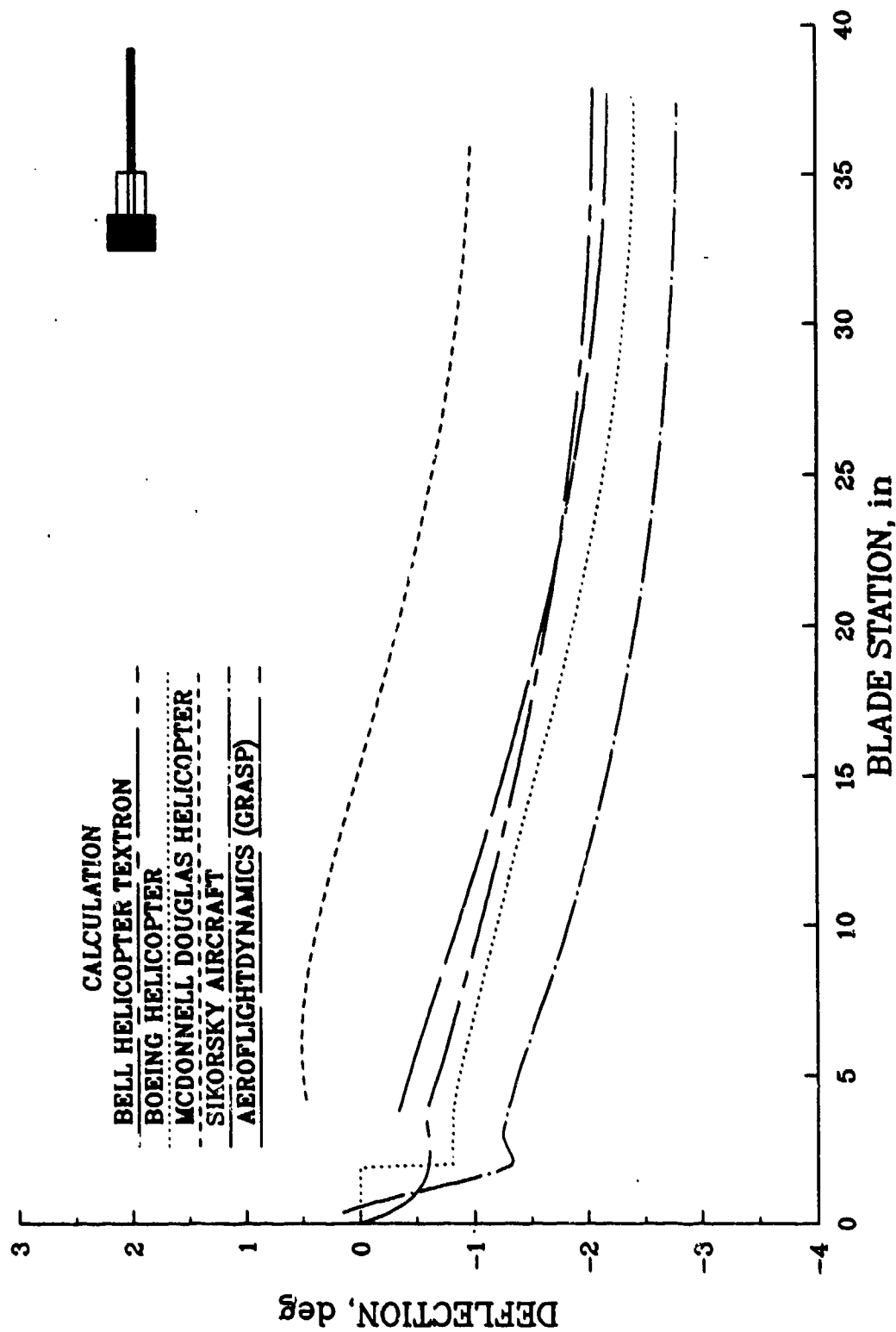


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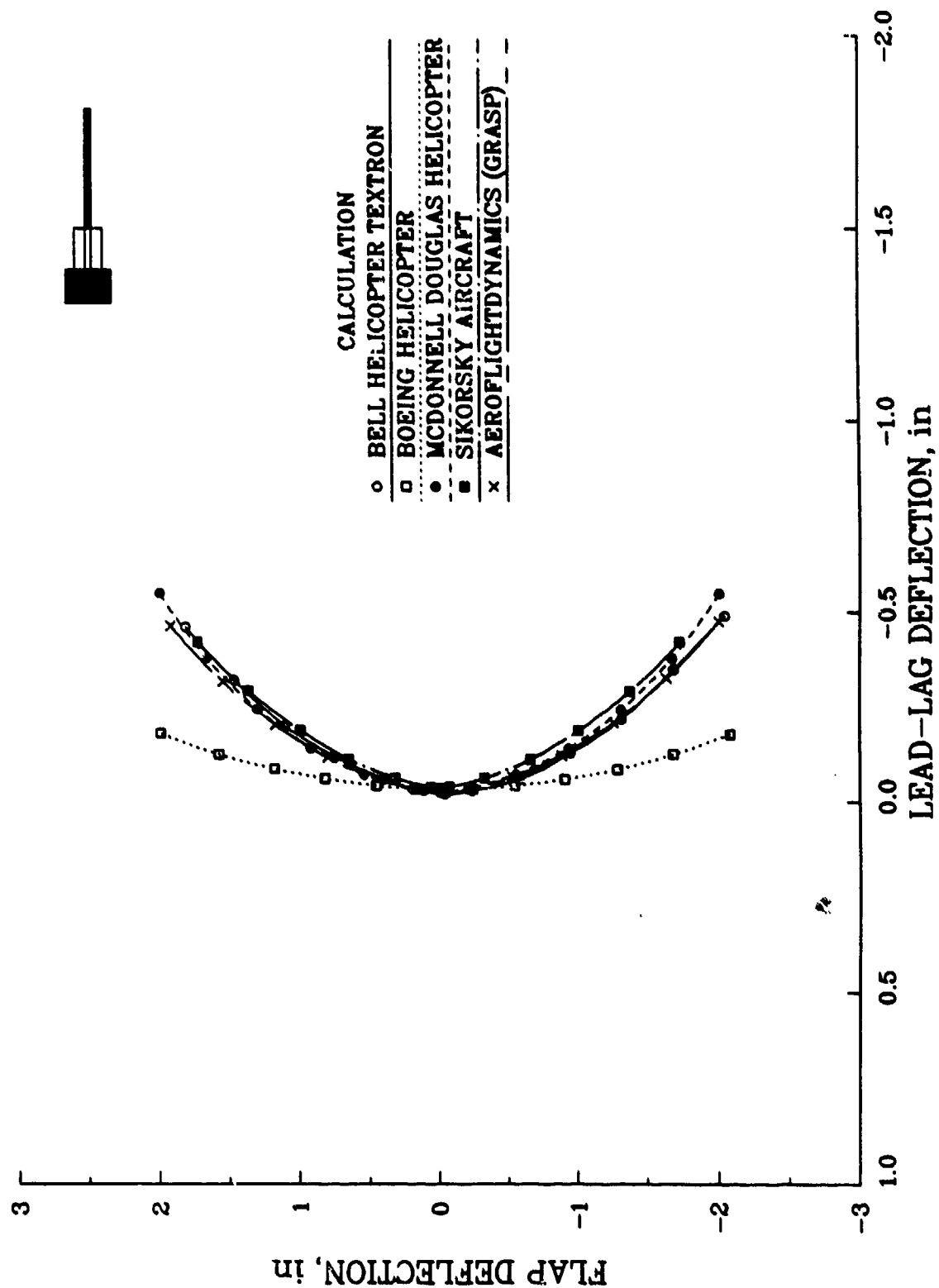
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### CASE 2 - TORSIONALLY SOFT ROTOR

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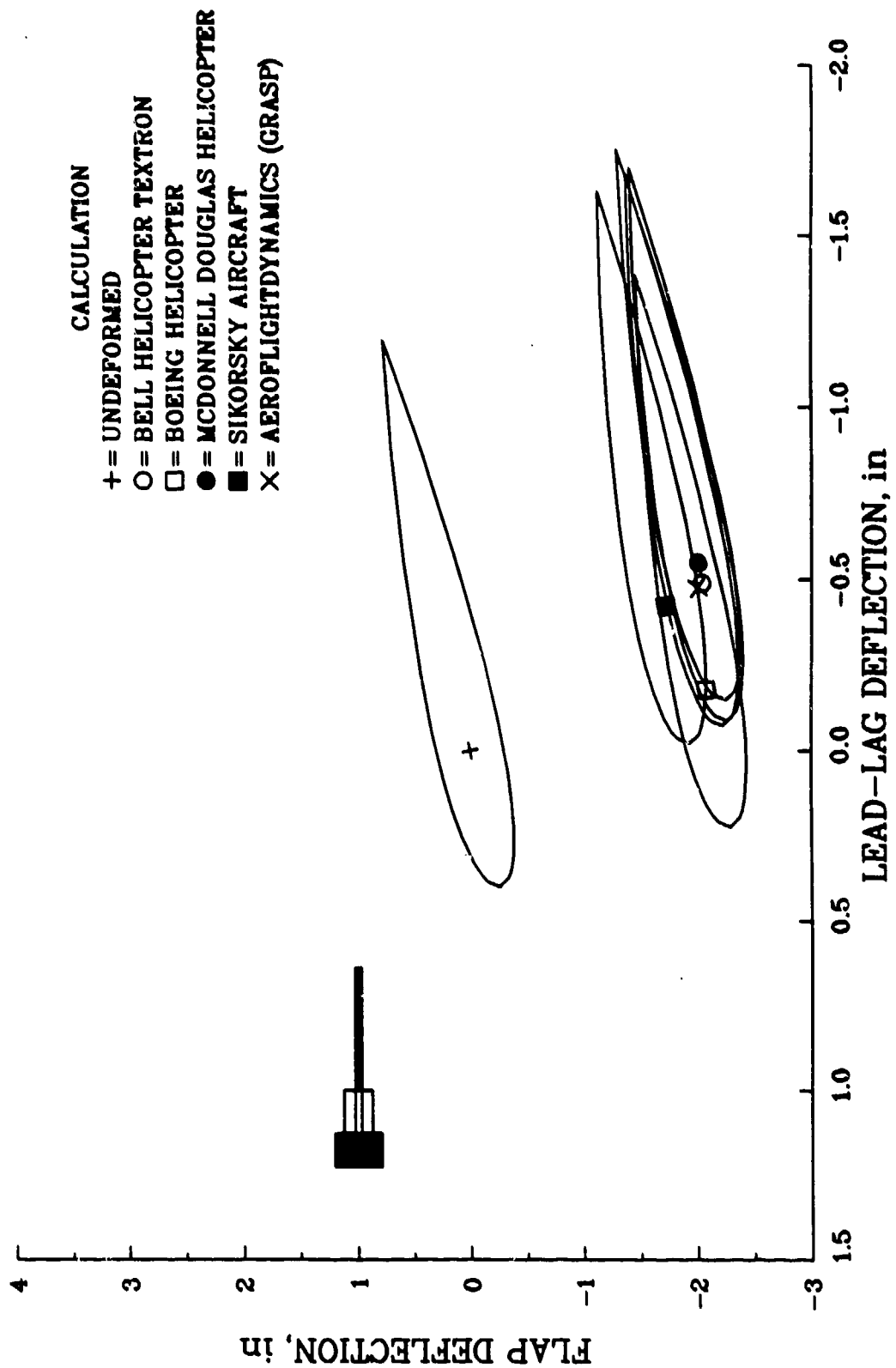


BLADE TIP DEFLECTION - TASK 86d  
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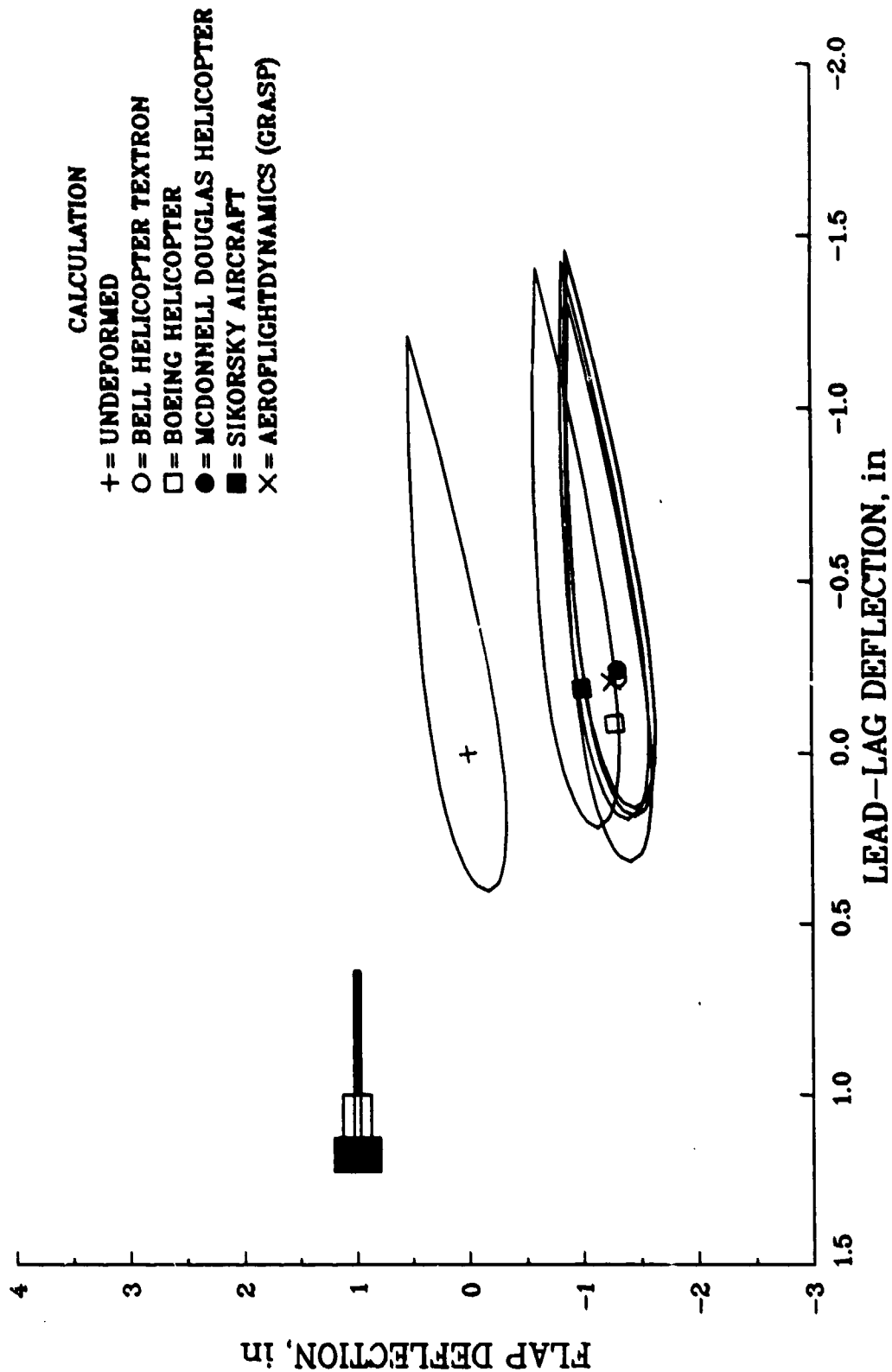


BLADE TIP DEFLECTION - TASK 86d  
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 CASE 2 - TORSIONALLY SOFT ROTOR

PITCH ANGLE = -12 deg



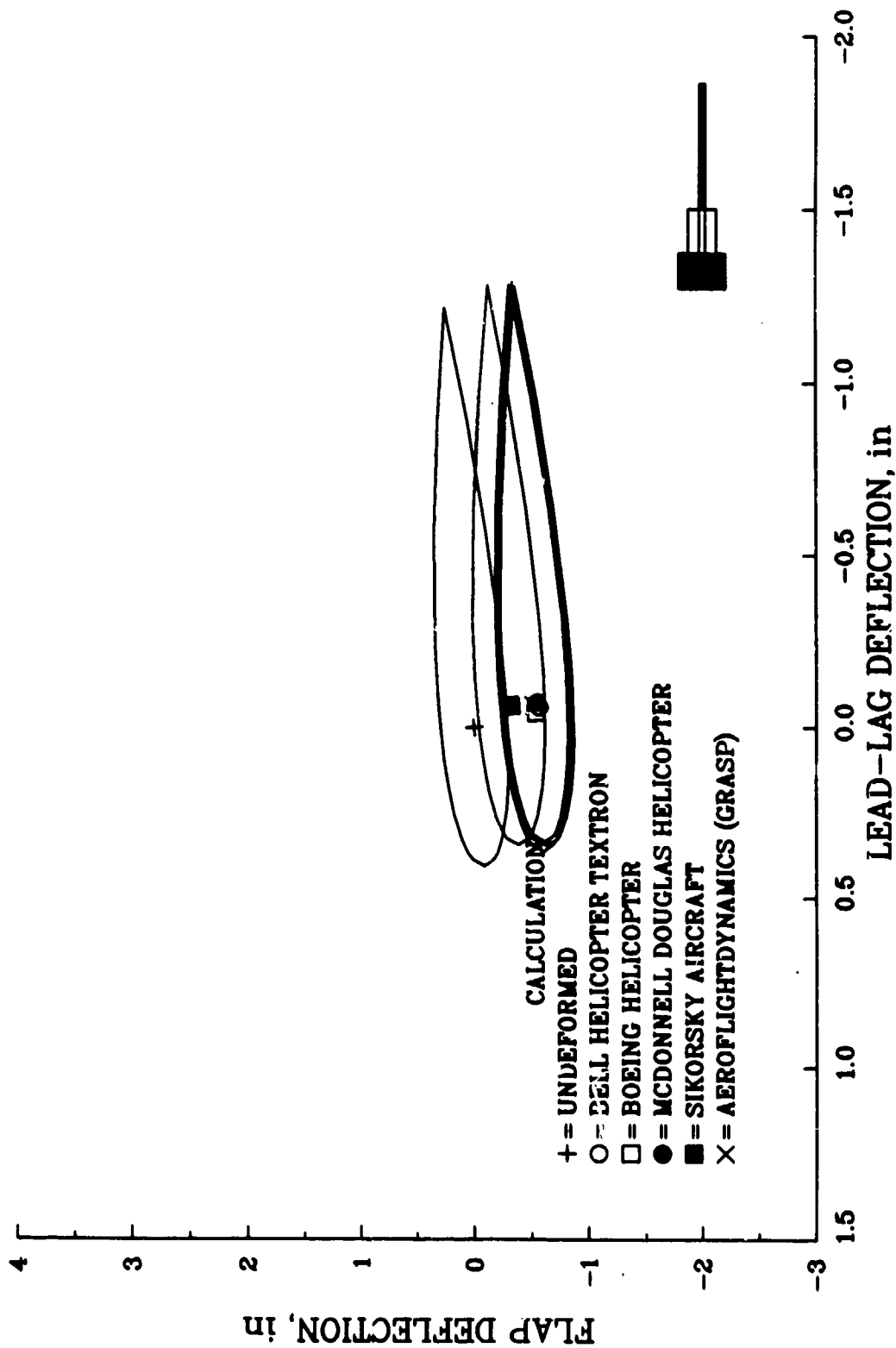
BLADE TIP DEFLECTION - TASK 86d  
 NONLINEAR AERODYNAMIC COEFFICIENTS  
 CASE 2 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = -8 deg



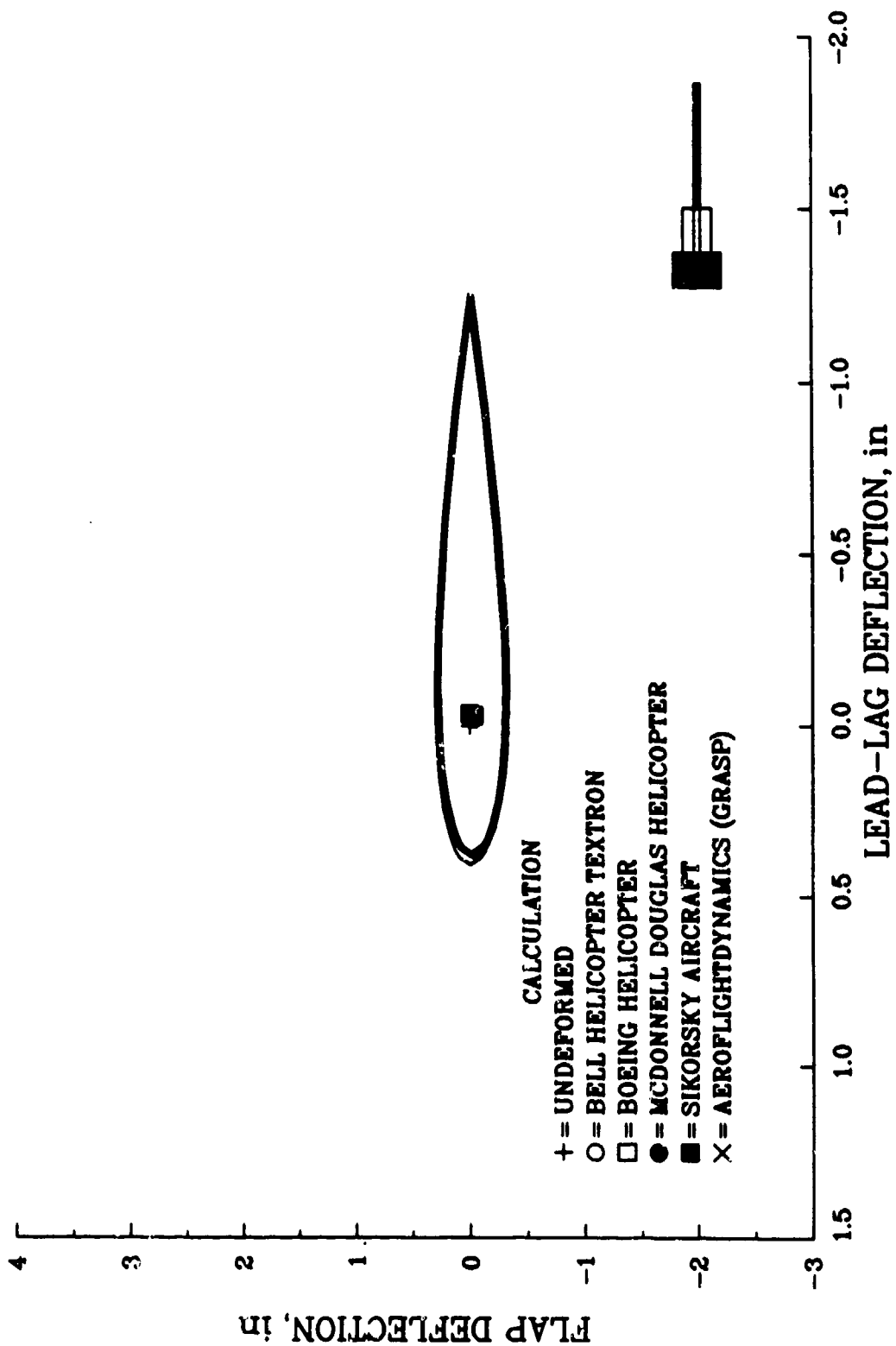


BLADE TIP DEFLECTION - TASK 86d  
 NONLINEAR AERODYNAMIC COEFFICIENTS  
 CASE 2 - TORSIONALLY SOFT ROTOR

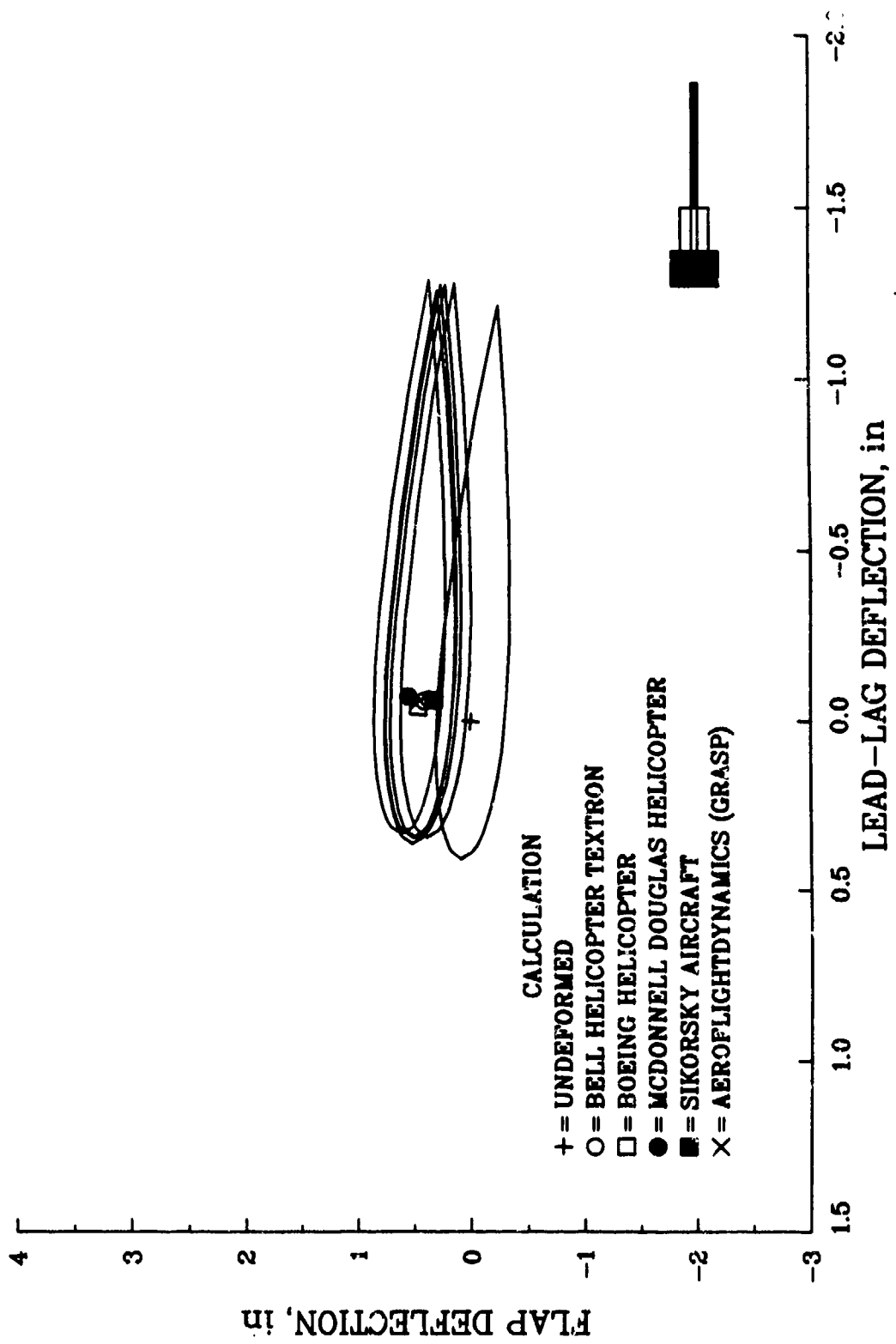
PITCH ANGLE = -4 deg



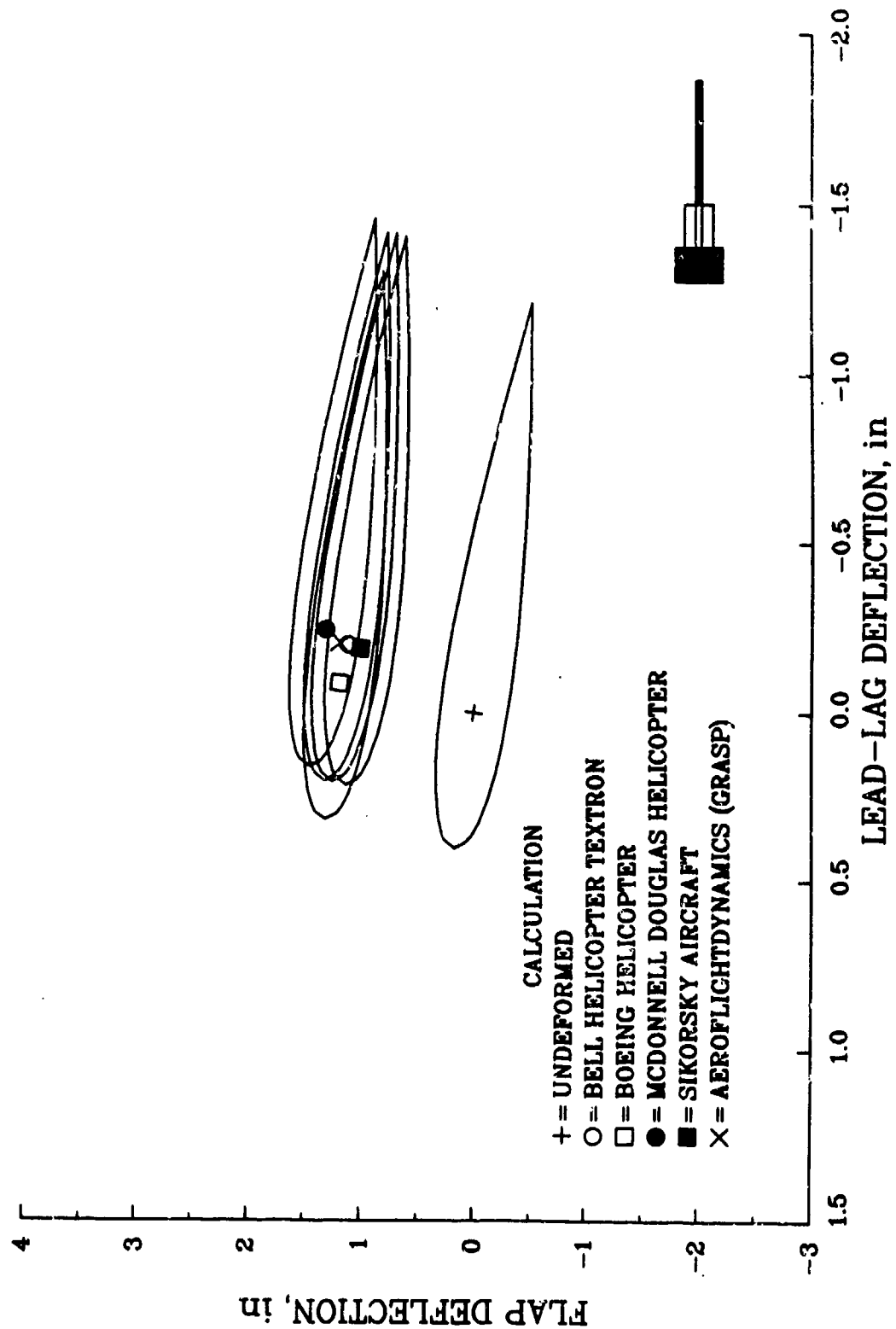
BLADE TIP DEFLECTION - TASK 86d  
 NONLINEAR AERODYNAMIC COEFFICIENTS  
 CASE 2 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = 0 deg



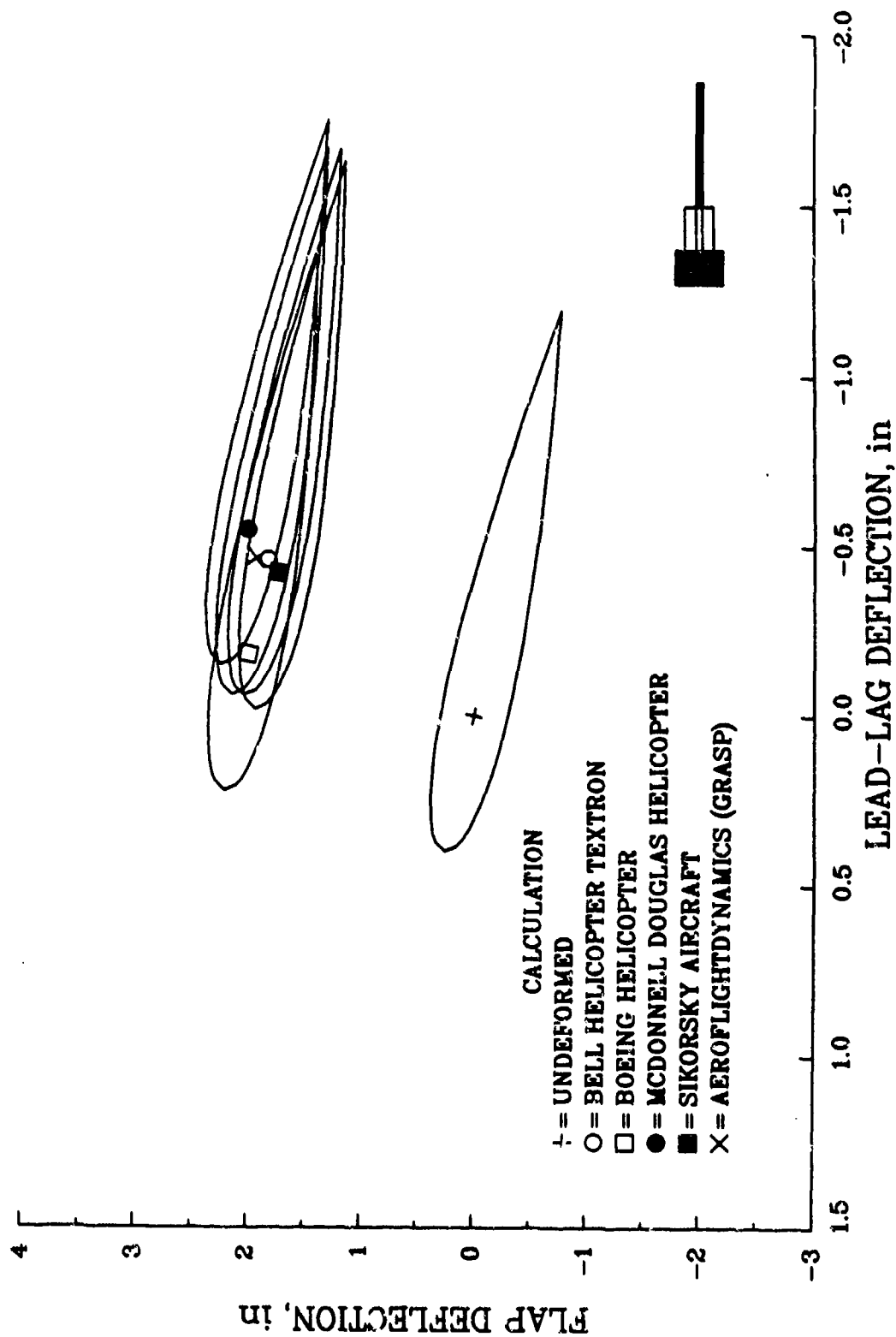
BLADE TIP DEFLECTION - TASK 86d  
 NONLINEAR AERODYNAMIC COEFFICIENTS  
 CASE 2 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = 4 deg



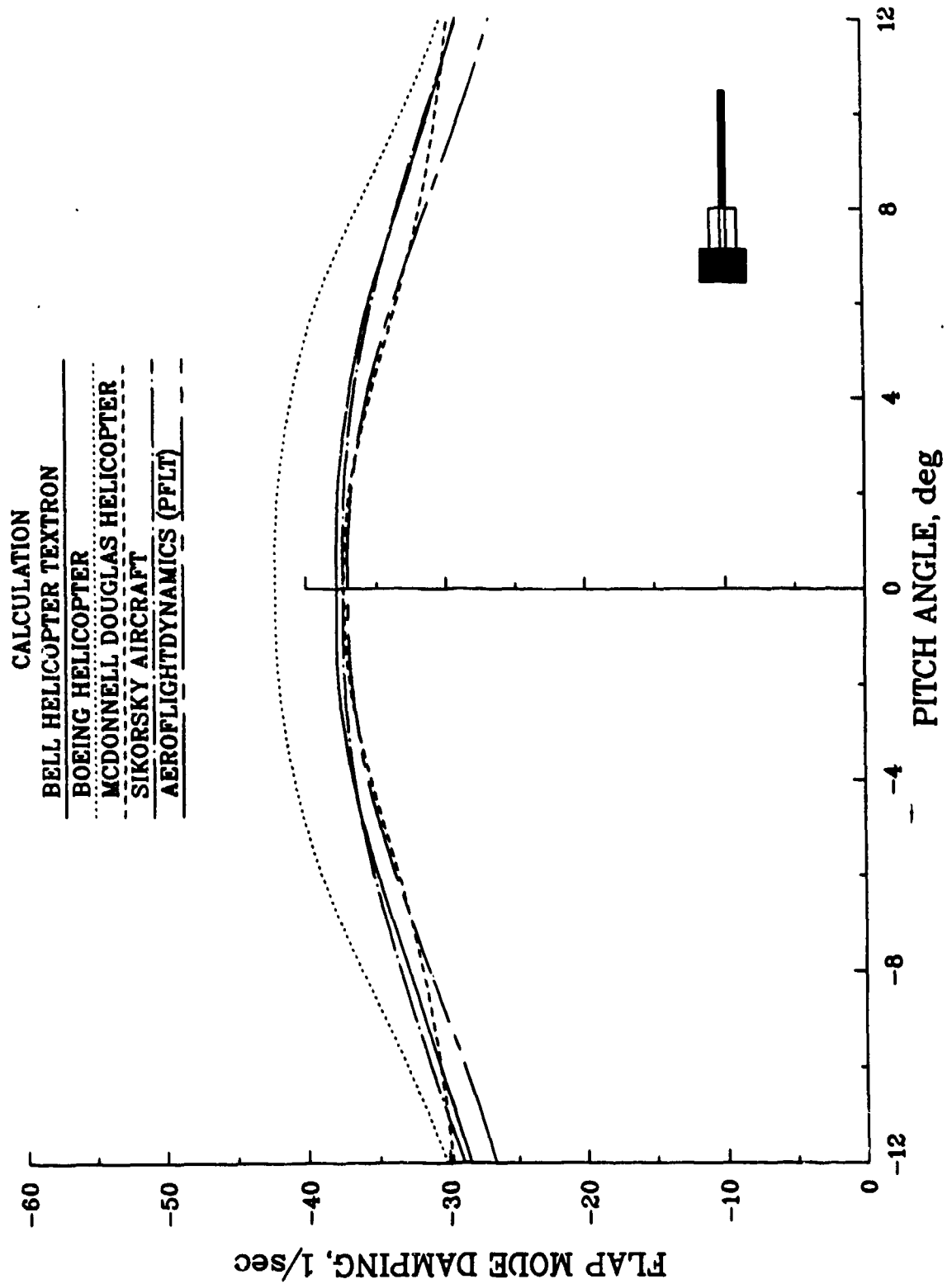
BLADE TIP DEFLECTION - TASK 86d  
 NONLINEAR AERODYNAMIC COEFFICIENTS  
 CASE 2 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = 8 deg



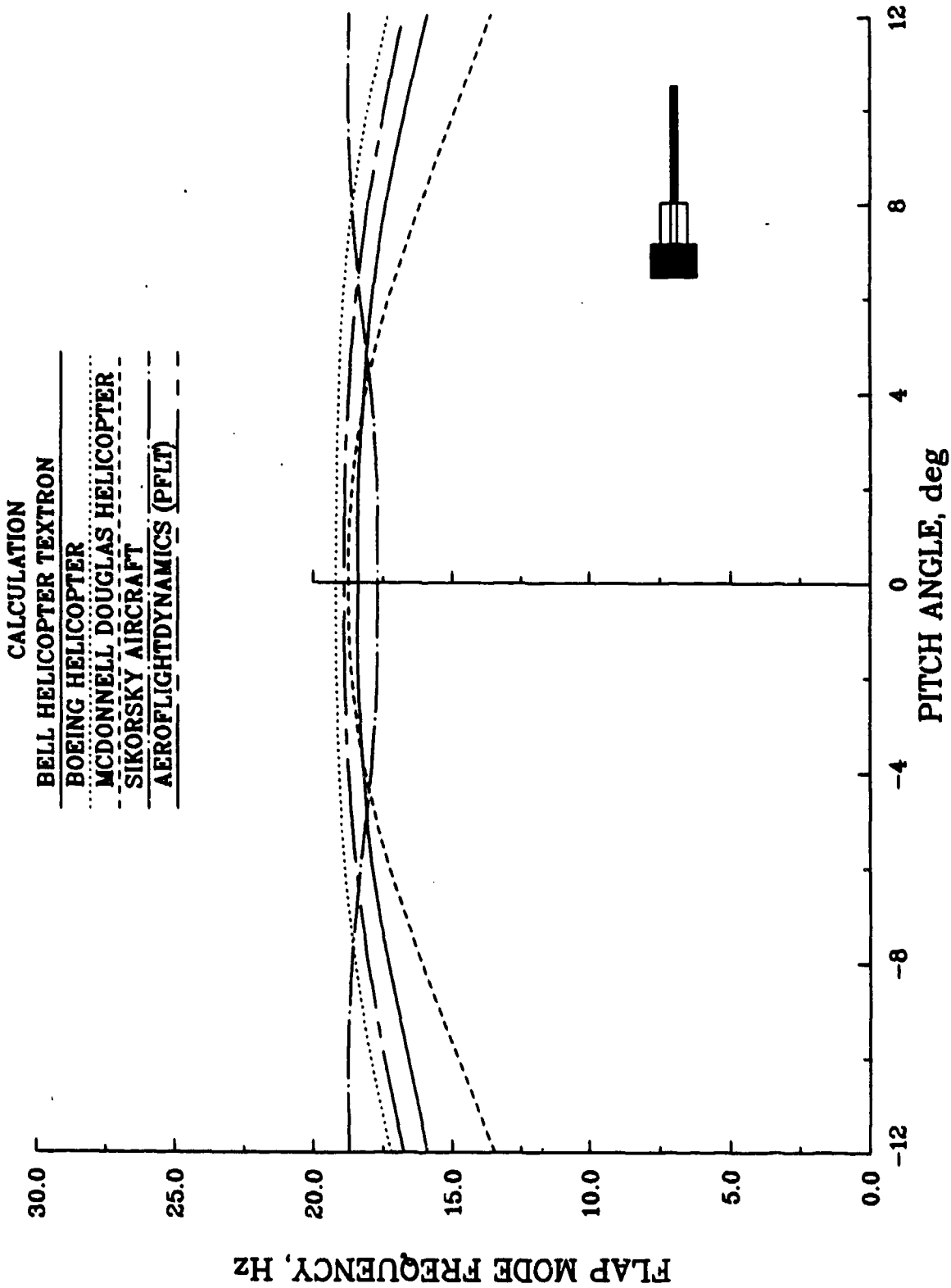
BLADE TIP DEFLECTION - TASK 86d  
 NONLINEAR AERODYNAMIC COEFFICIENTS  
 CASE 2 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = 12 deg



FLAP MODE DAMPING - TASK 86e  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 2 - TORSIONALLY SOFT ROTOR

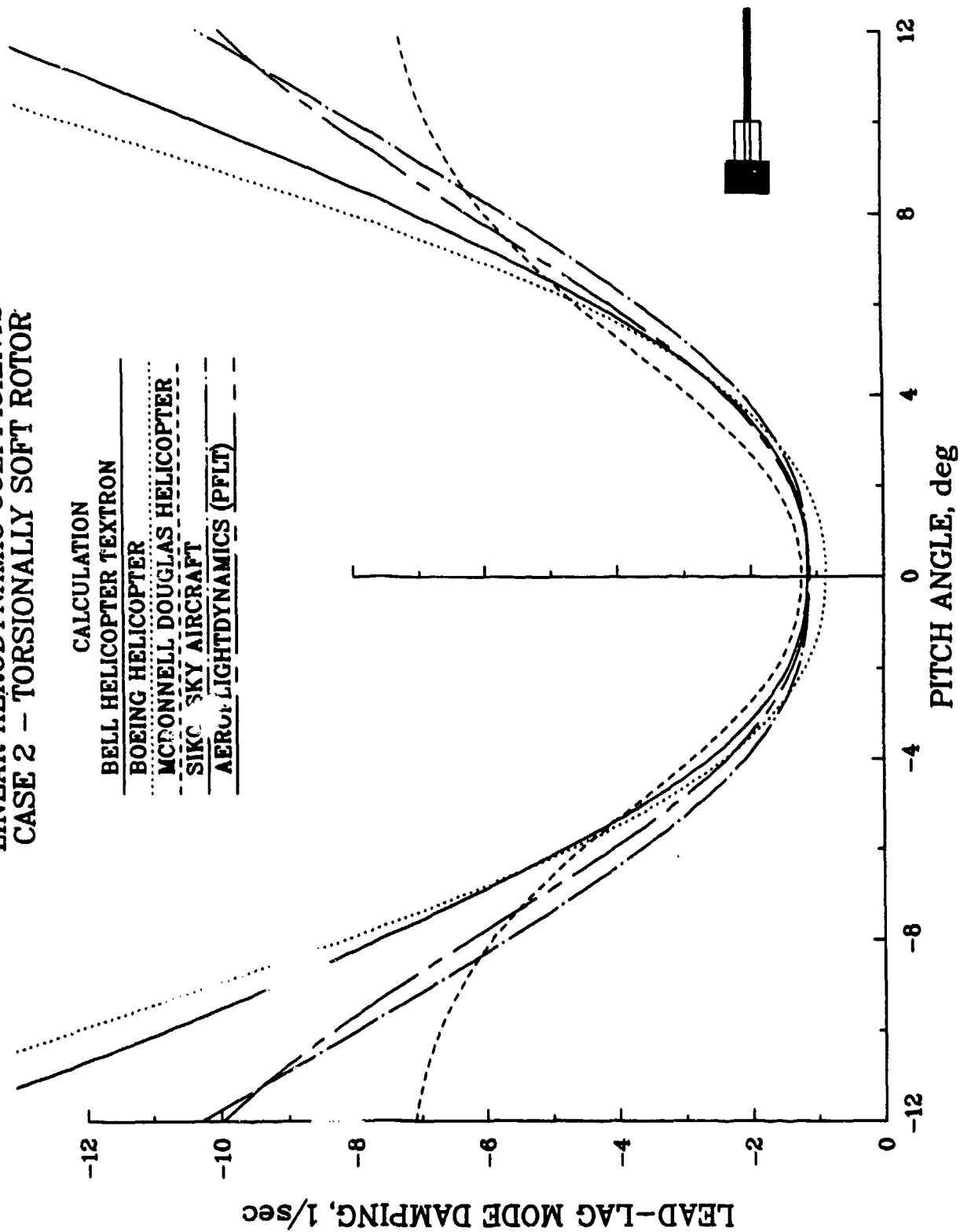


FLAP MODE FREQUENCY - TASK 86e  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 2 - TORSIONALLY SOFT ROTOR



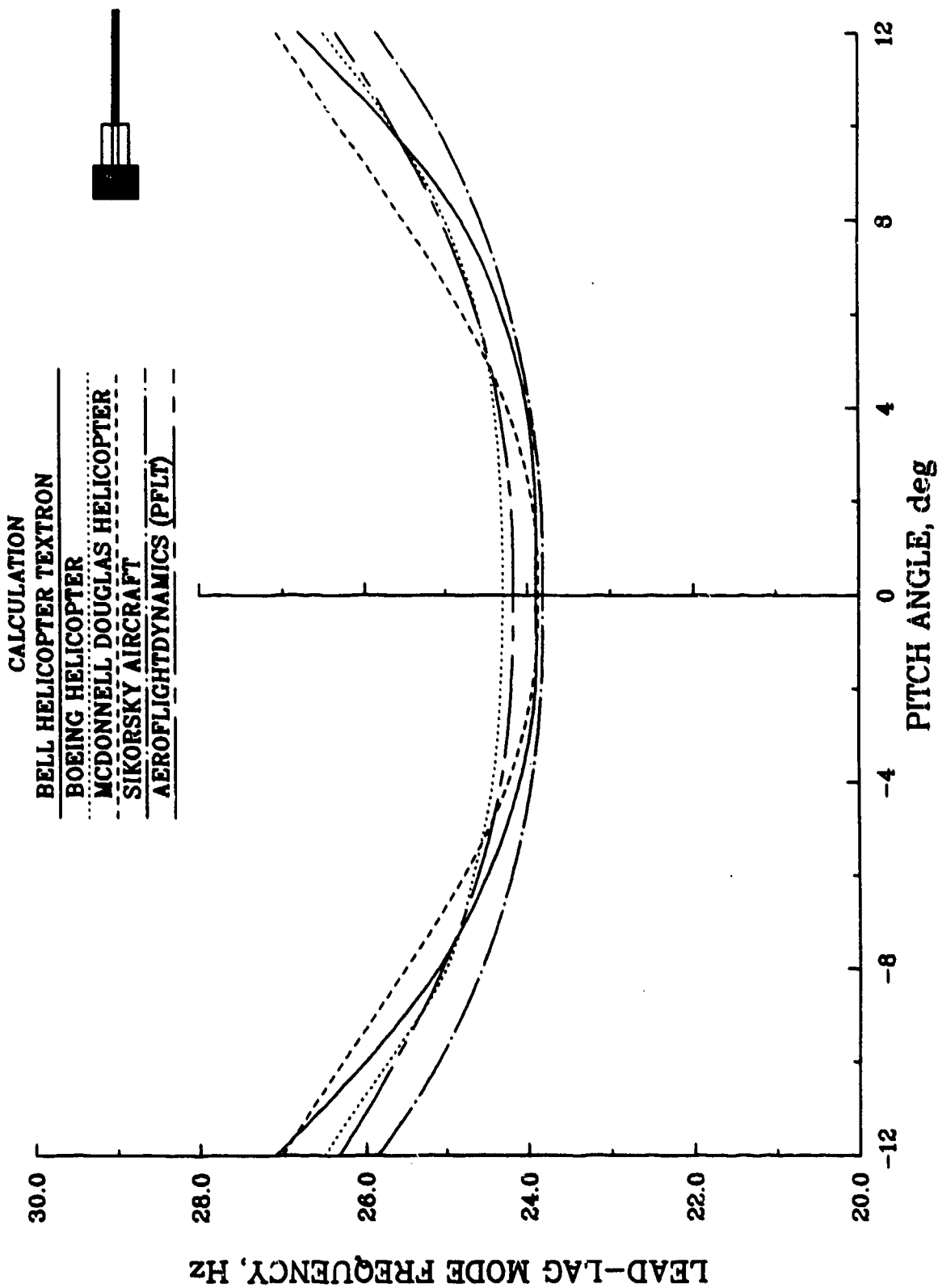
LEAD-LAG MODE DAMPING - TASK 86e  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 2 - TORSIONALLY SOFT ROTOR

CALCULATION	
BELL HELICOPTER TEXTRON	—
BOEING HELICOPTER	—
MCDONNELL DOUGLAS HELICOPTER	- - -
SIKIC SKY AIRCRAFT	- - -
AEROUT LIGHTDYNAMICS (PFLT)	- - -

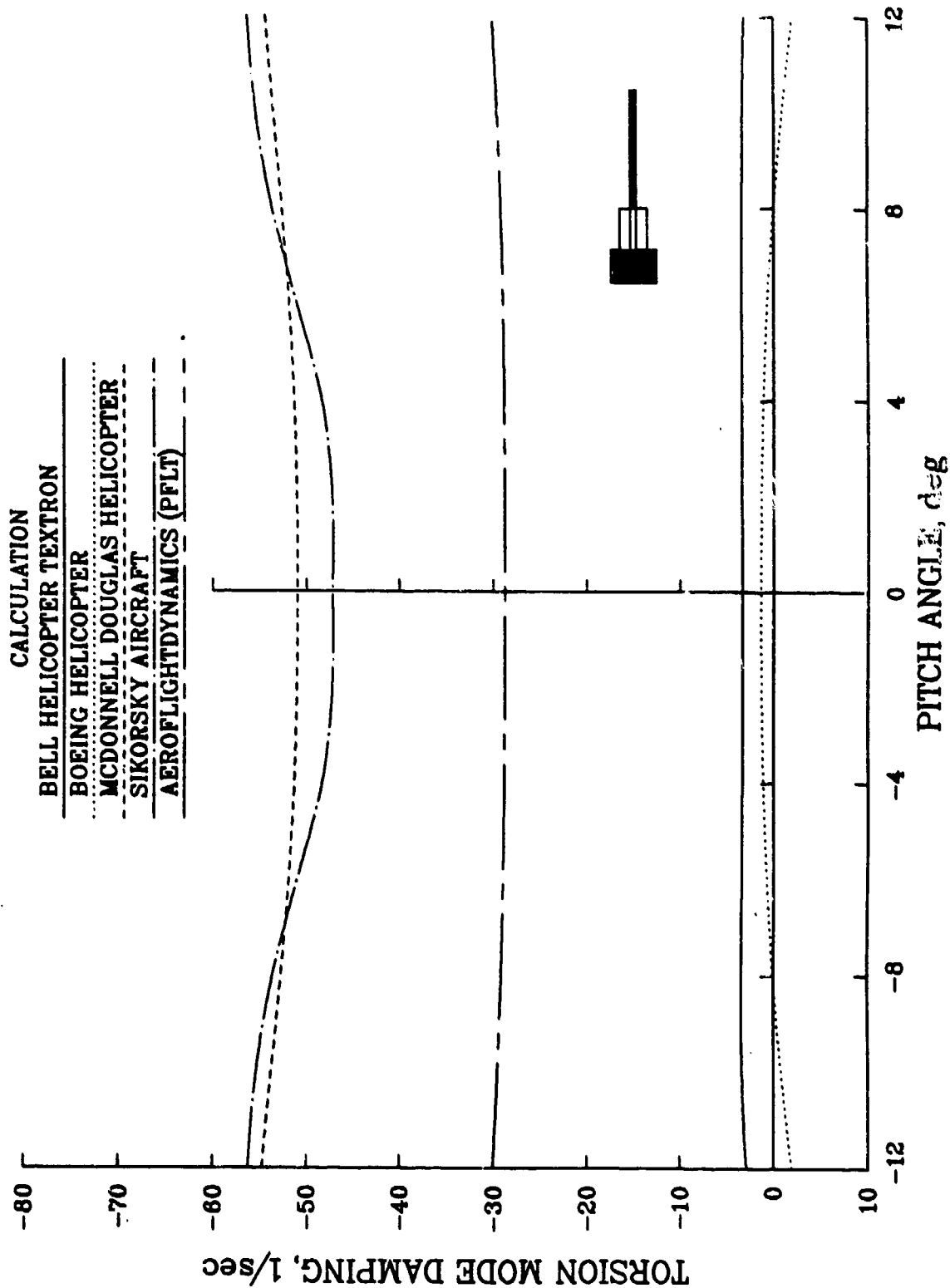




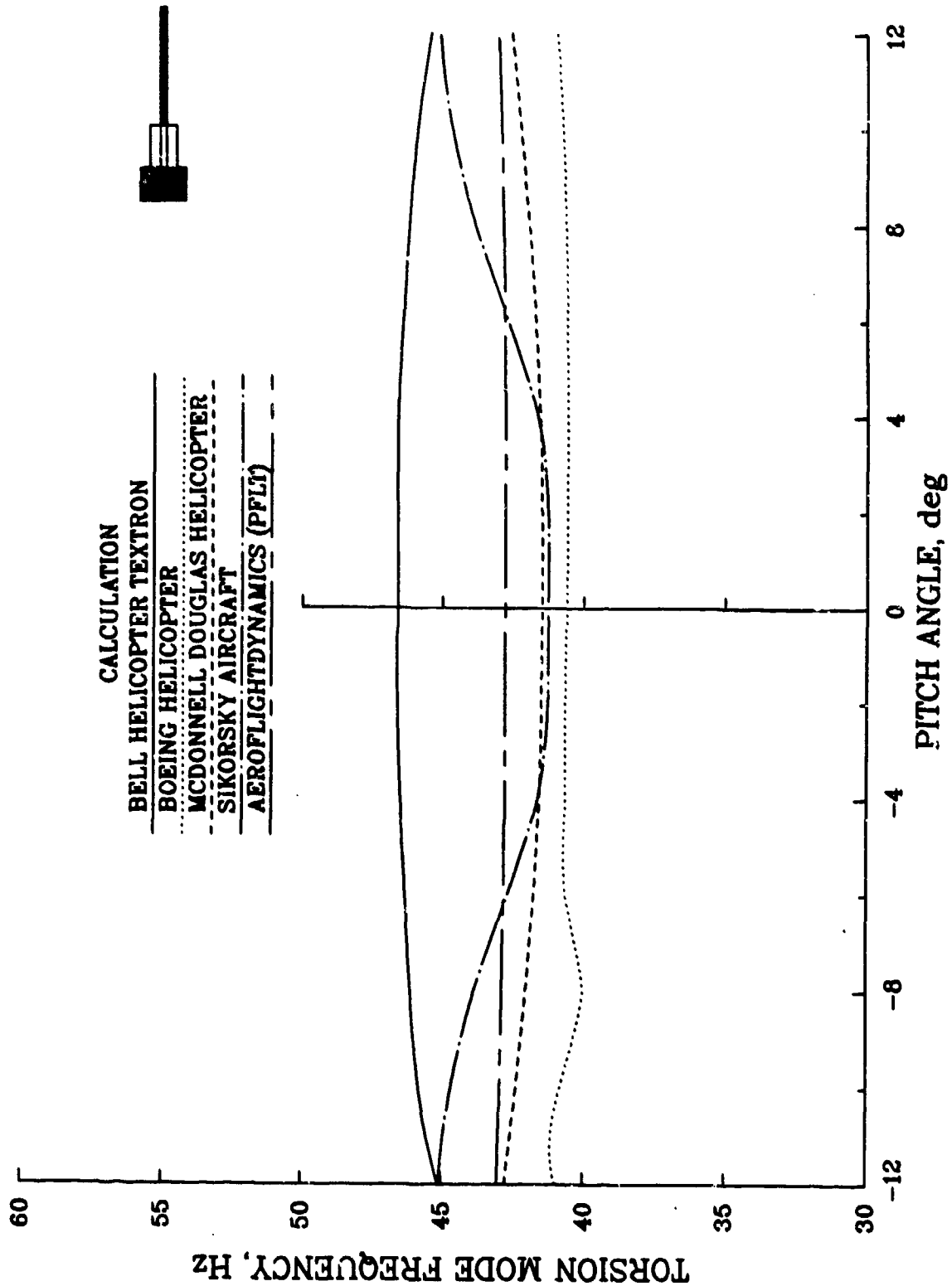
# LEAD-LAG MODE FREQUENCY - TASK 86e LINEAR AERODYNAMIC COEFFICIENTS CASE 2 - TORSIONALLY SOFT ROTOR



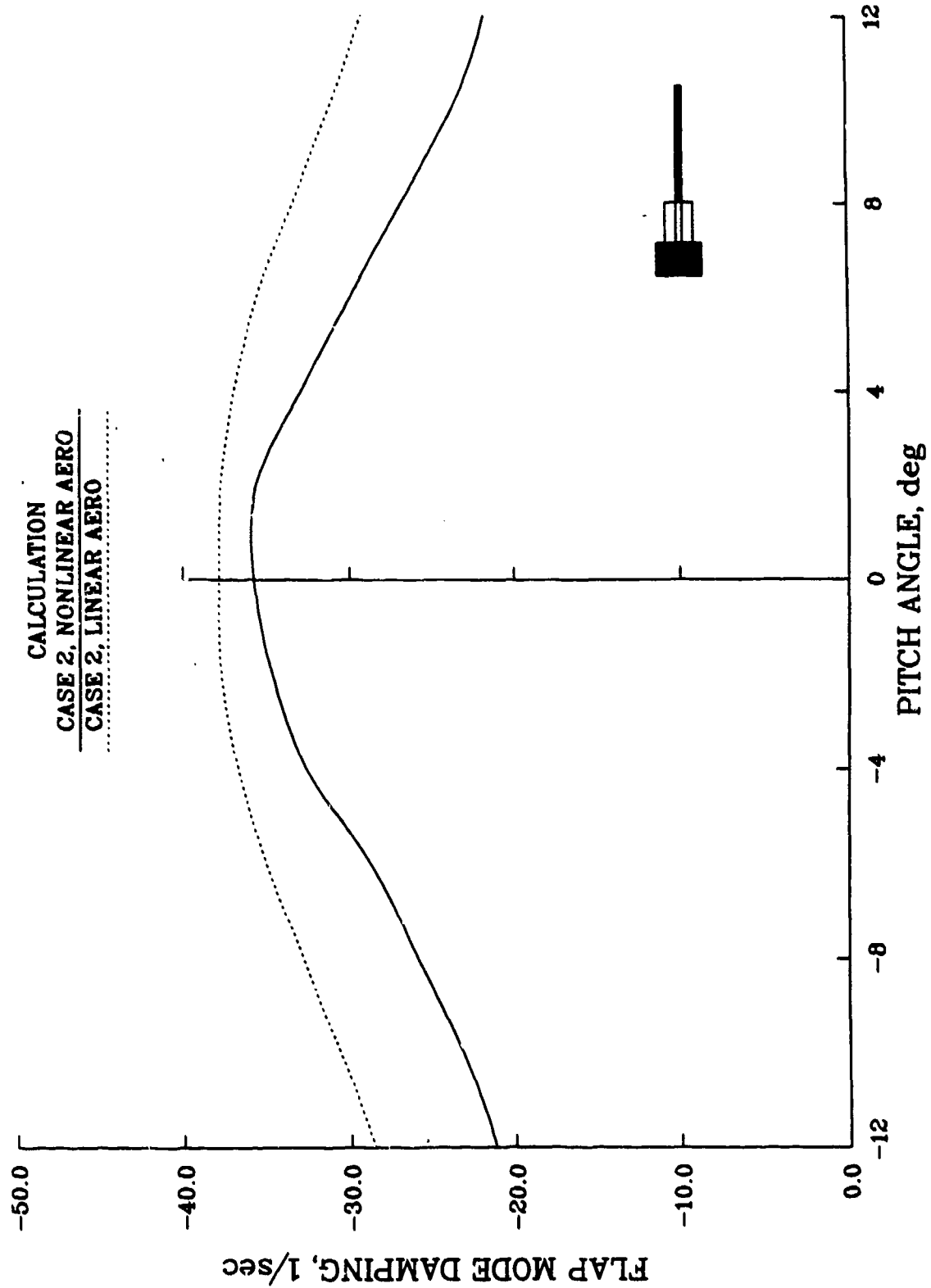
**TORSION MODE DAMPING - TASK 86e**  
**LINEAR AERODYNAMIC COEFFICIENTS**  
**CASE 2 - TORSIONALLY SOFT ROTOR**



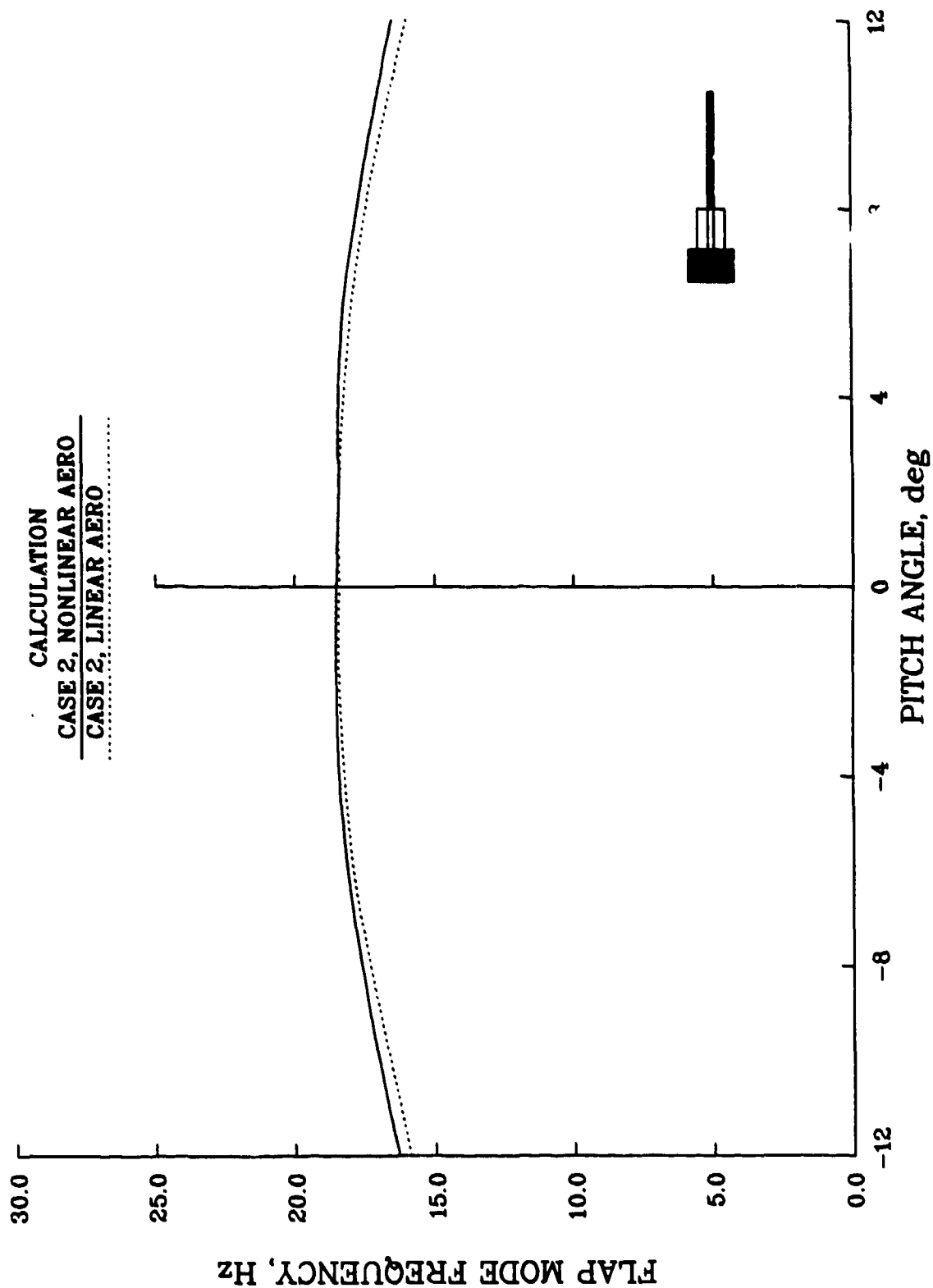
**TORSION MODE FREQUENCY - TASK 86e**  
**LINEAR AERODYNAMIC COEFFICIENTS**  
**CASE 2 - TORSIONALLY SOFT ROTOR**



# FLAP MODE DAMPING TORSIONALLY SOFT ROTOR BELL HELICOPTER TEXTRON

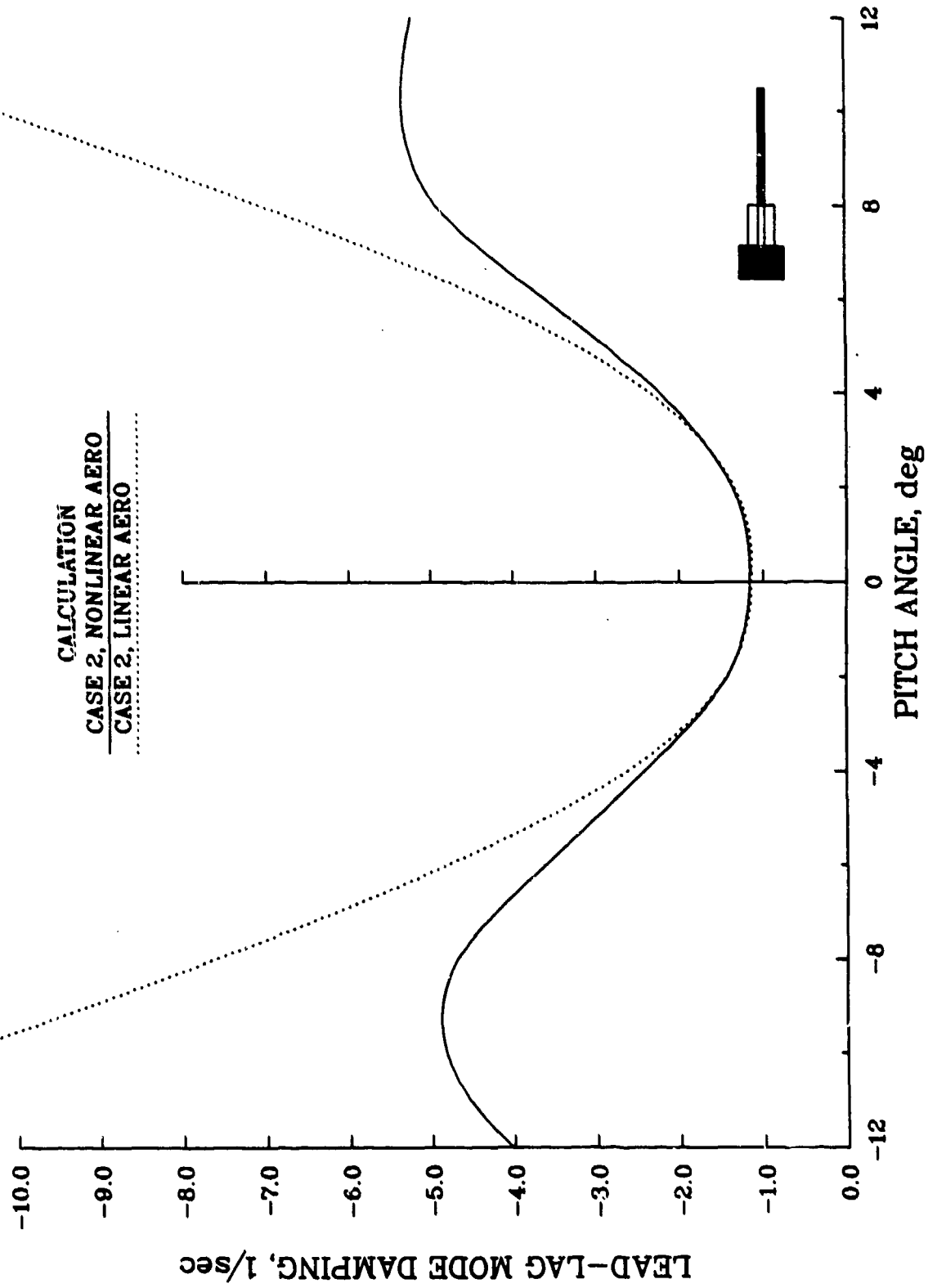


FLAP MODE FREQUENCY  
TORSIONALLY SOFT ROTOR  
BELL HELICOPTER TEXTRON

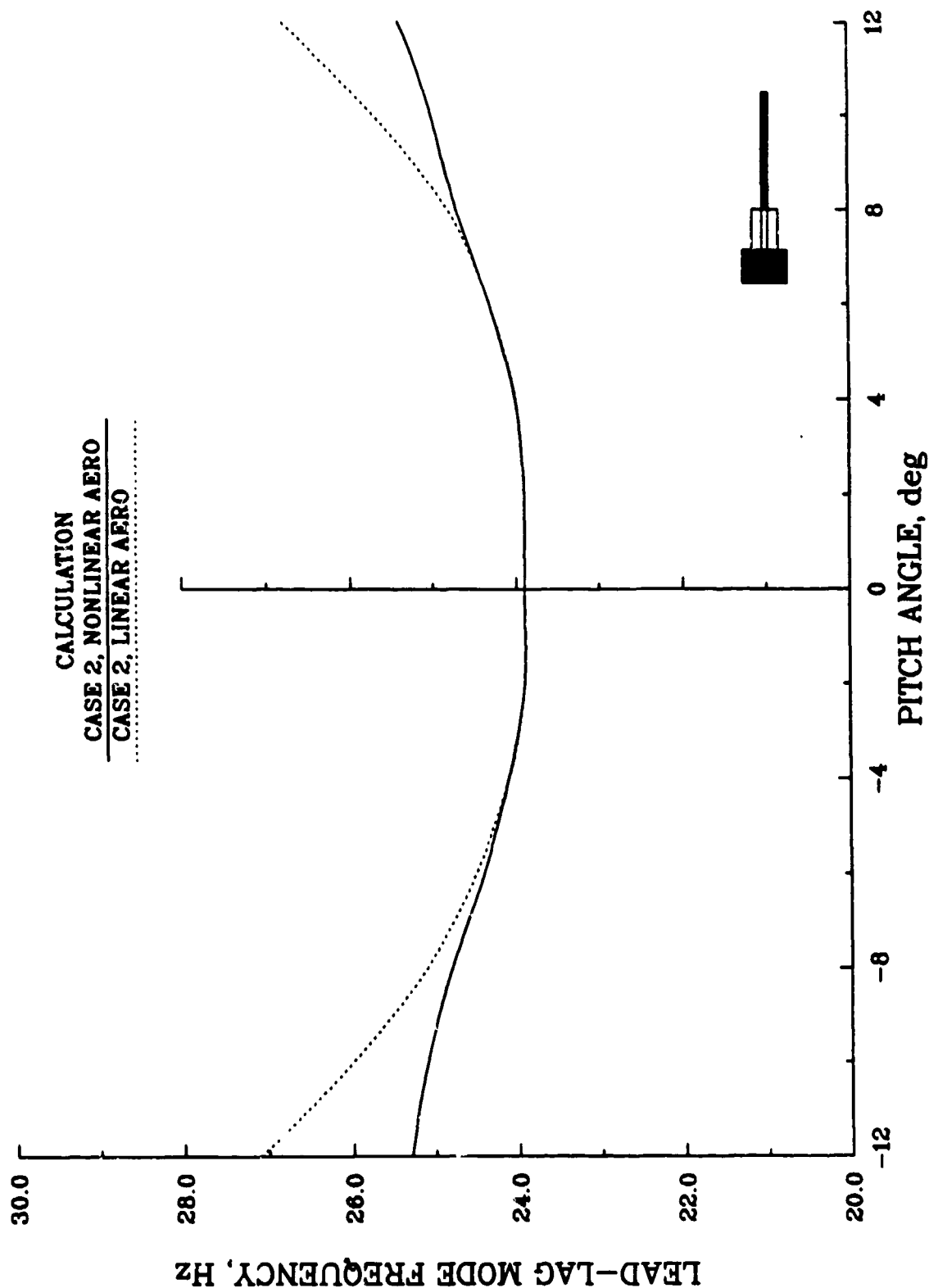


LEAD-LAG MODE DAMPING  
TORSIONALLY SOFT ROTOR  
BELL HELICOPTER TEXTRON

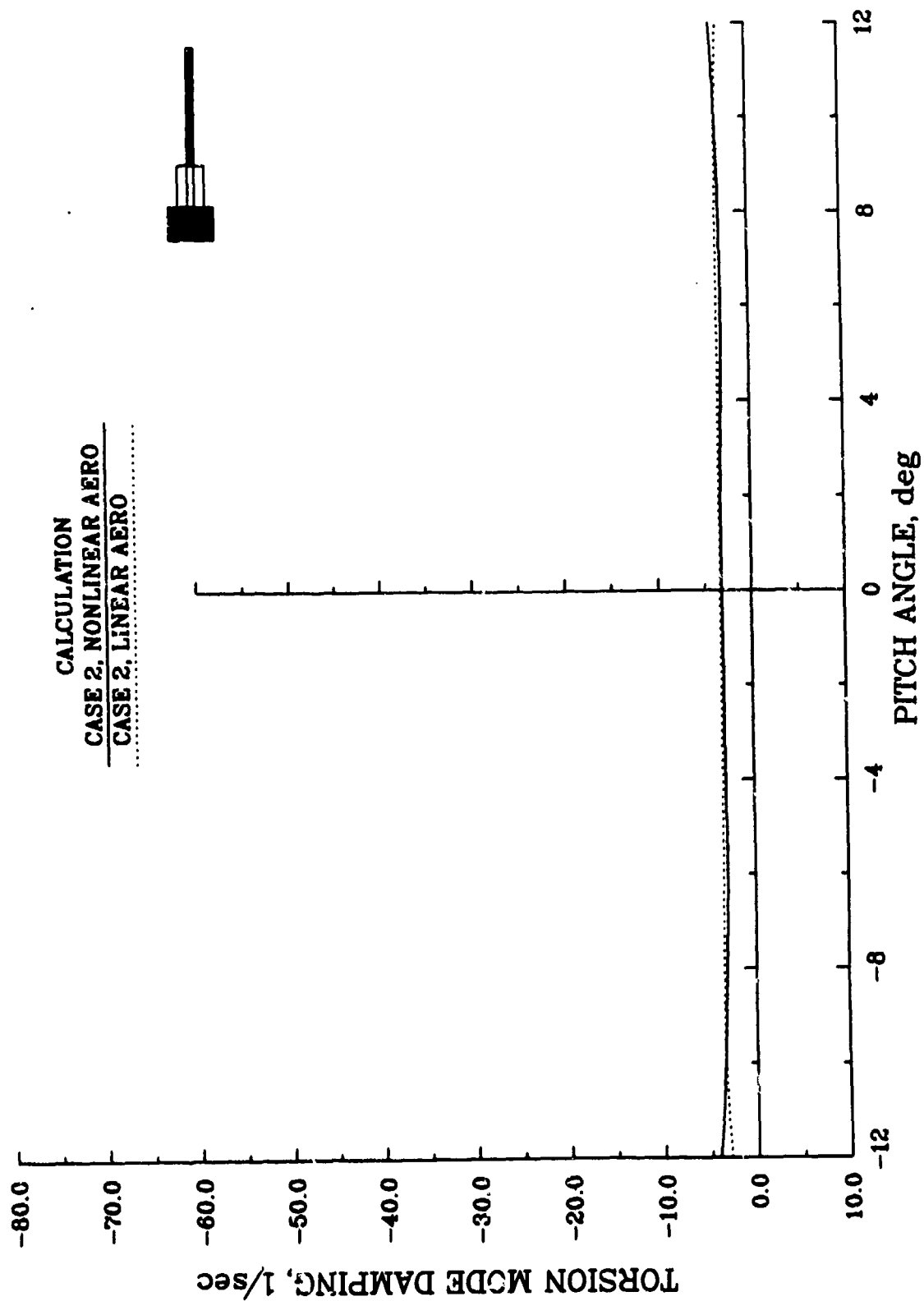
CALCULATION  
CASE 2, NONLINEAR AERO  
CASE 2, LINEAR AERO



# LEAD-LAG MODE FREQUENCY TORSIONALLY SOFT ROTOR BELL HELICOPTER TEXTRON

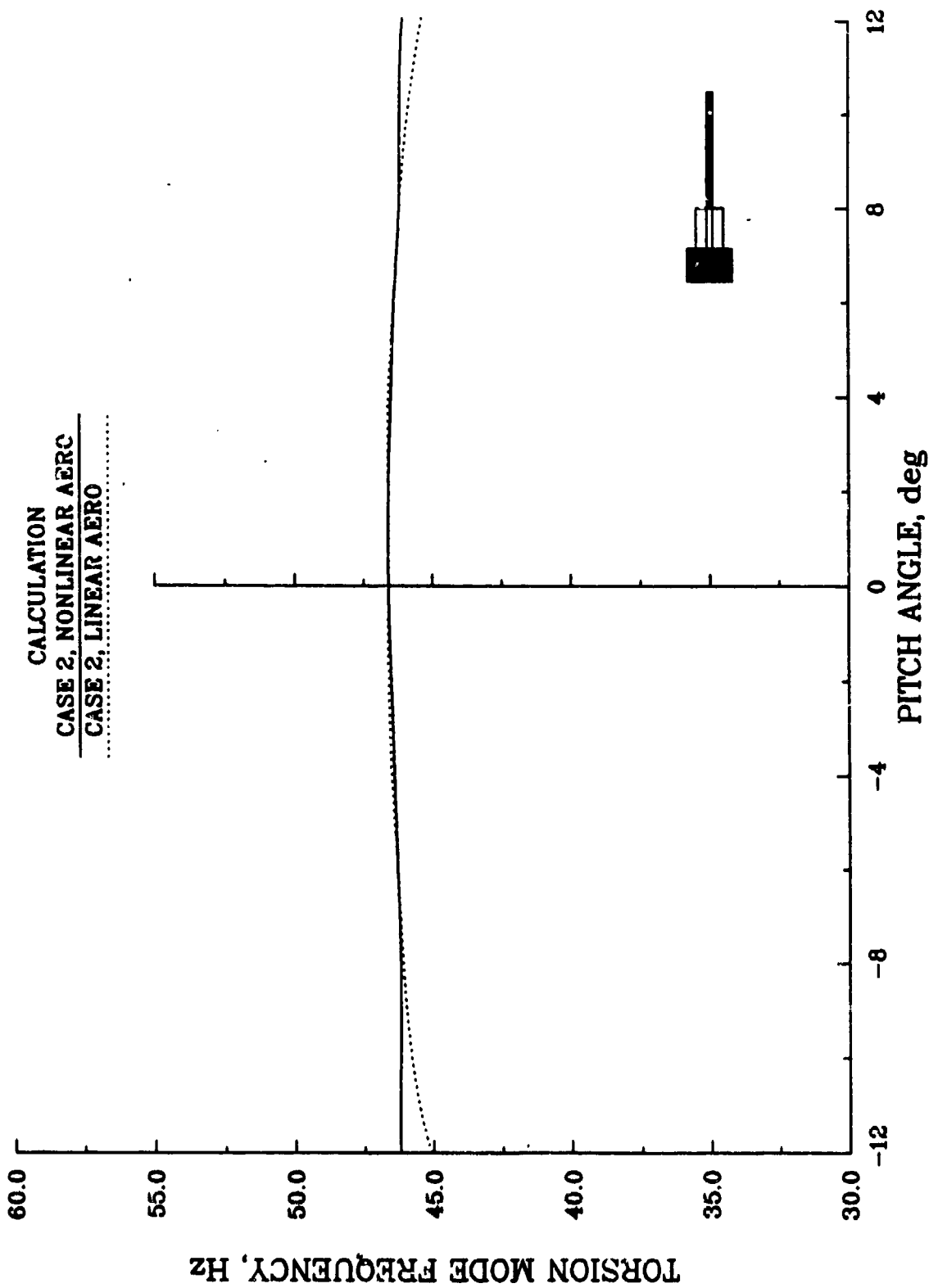


**TORSION MODE DAMPING  
TORSIONALLY SOFT ROTOR  
BELL HELICOPTER TEXTRON**

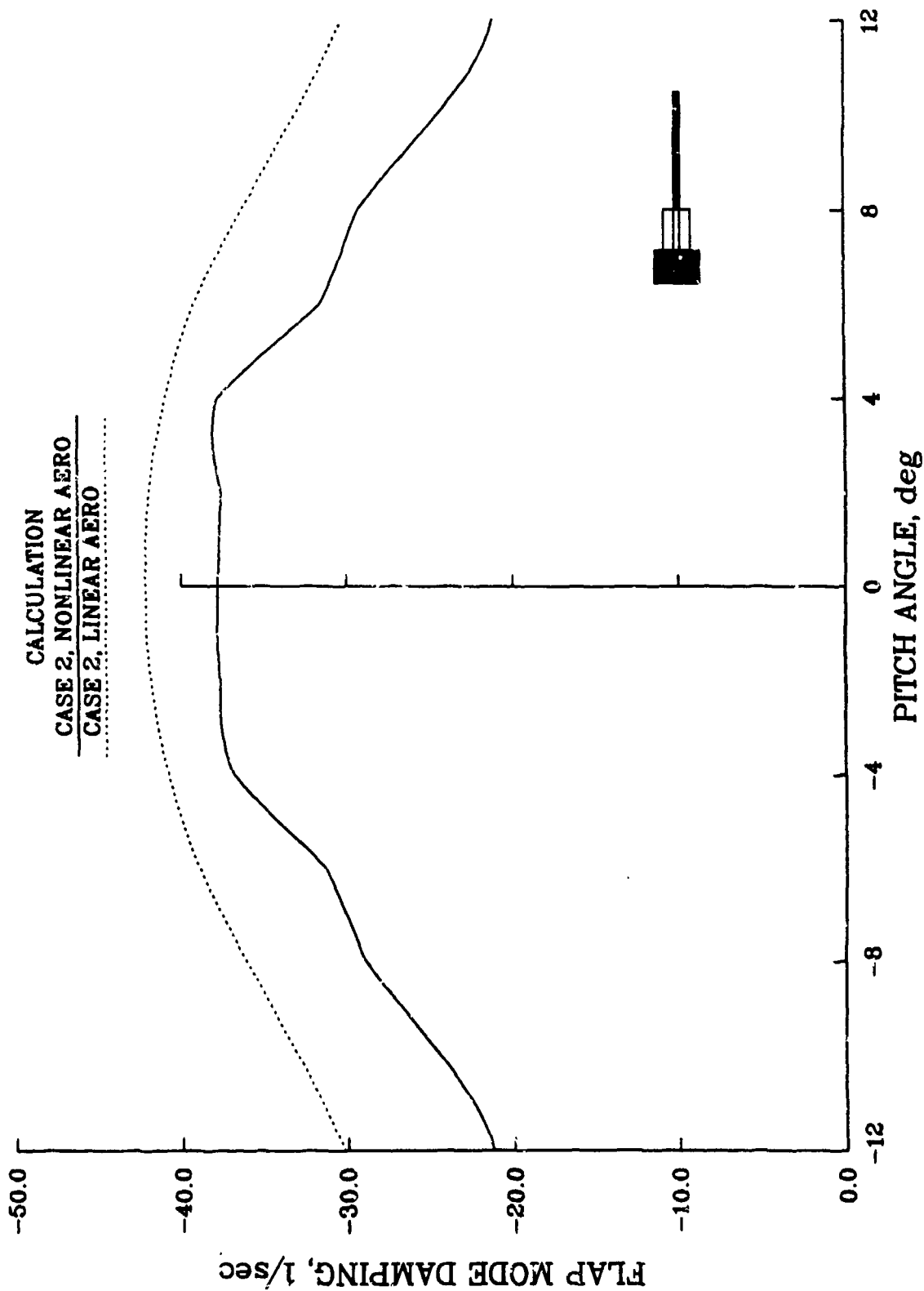




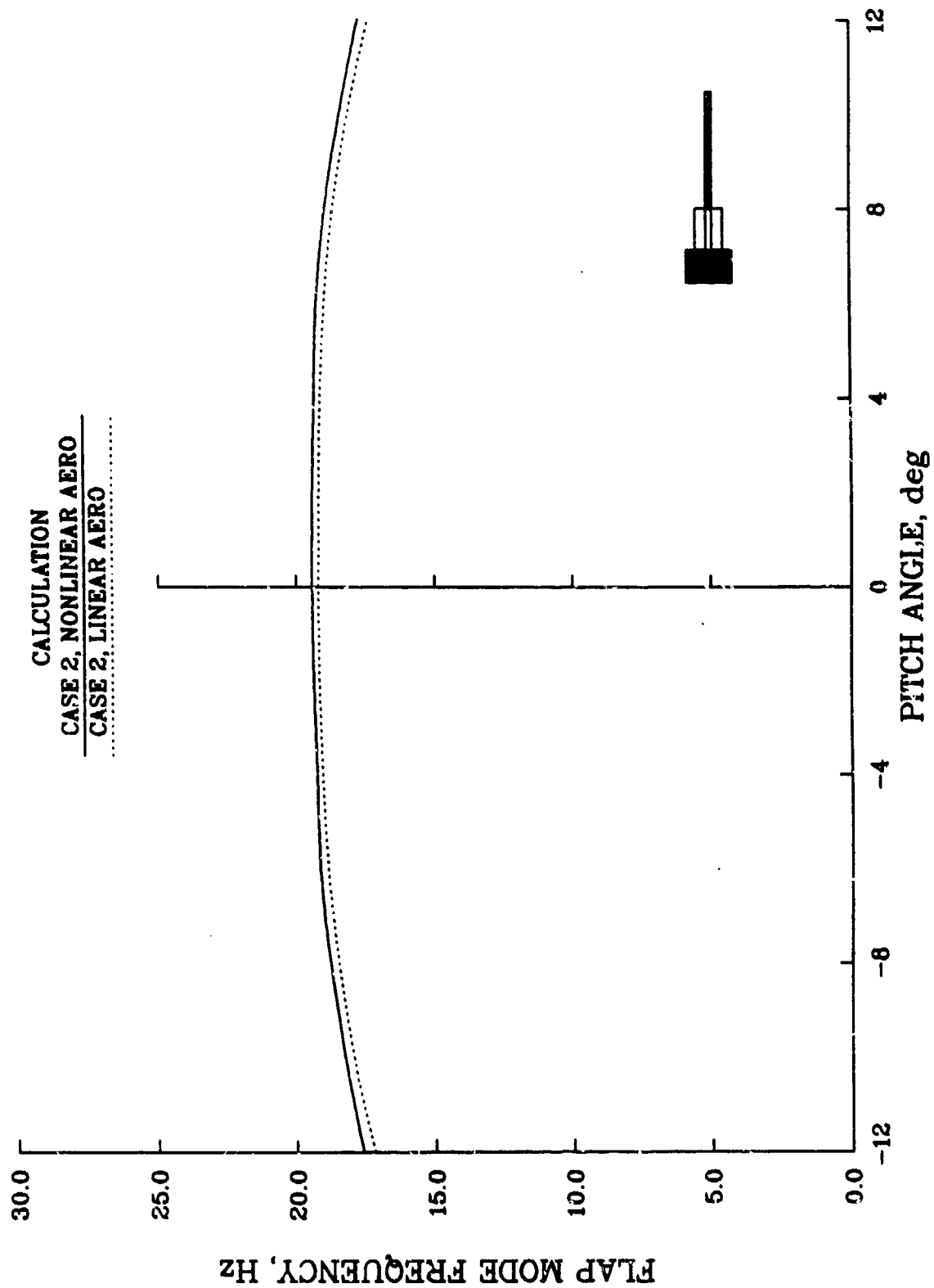
TORSION MODE FREQUENCY  
TORSIONALLY SOFT ROTOR  
BELL HELICOPTER TEXTRON



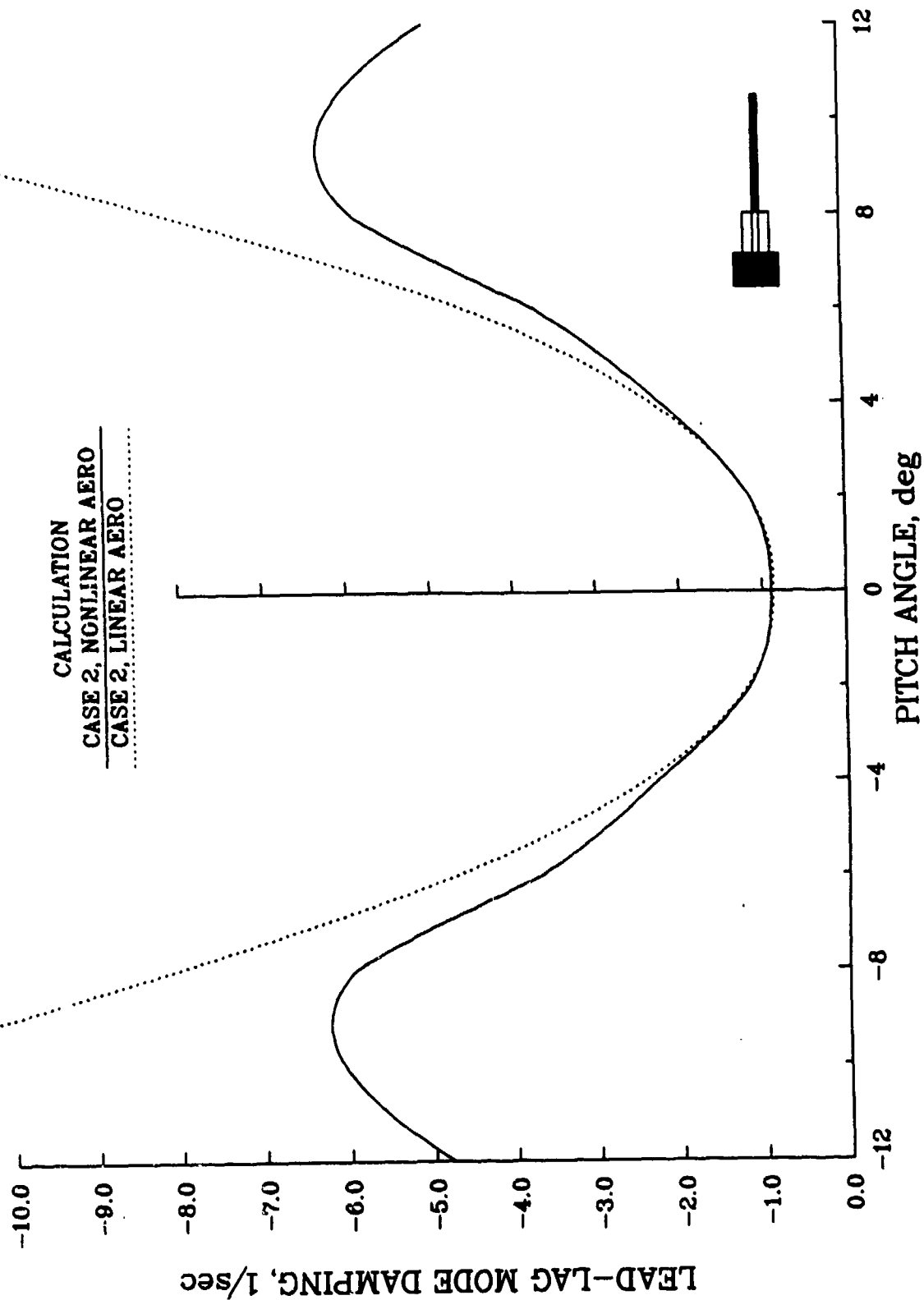
# FLAP MODE DAMPING TORSIONALLY SOFT ROTOR BOEING HELICOPTER



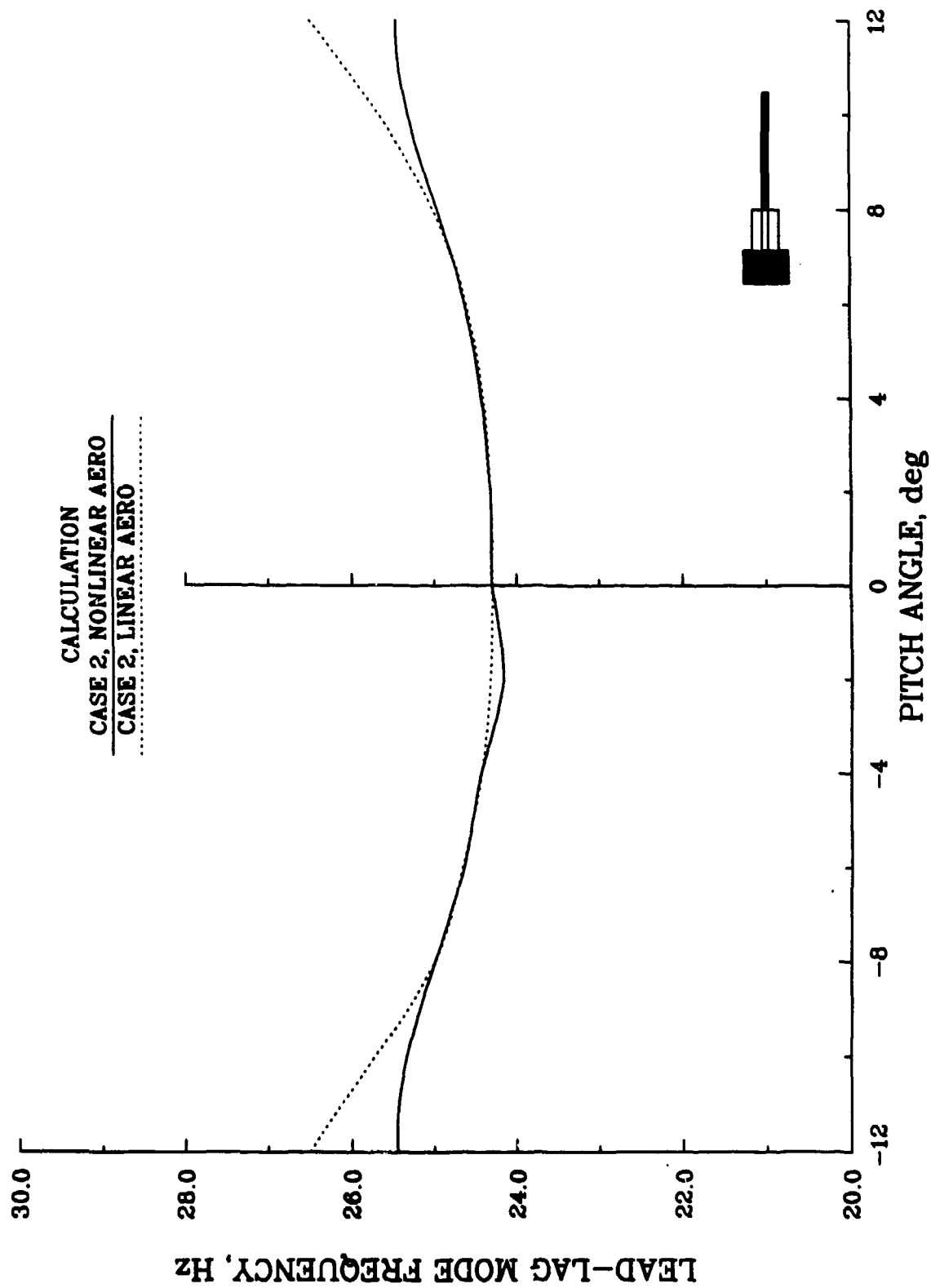
FLAP MODE FREQUENCY  
TORSIONALLY SOFT ROTOR  
BOEING HELICOPTER



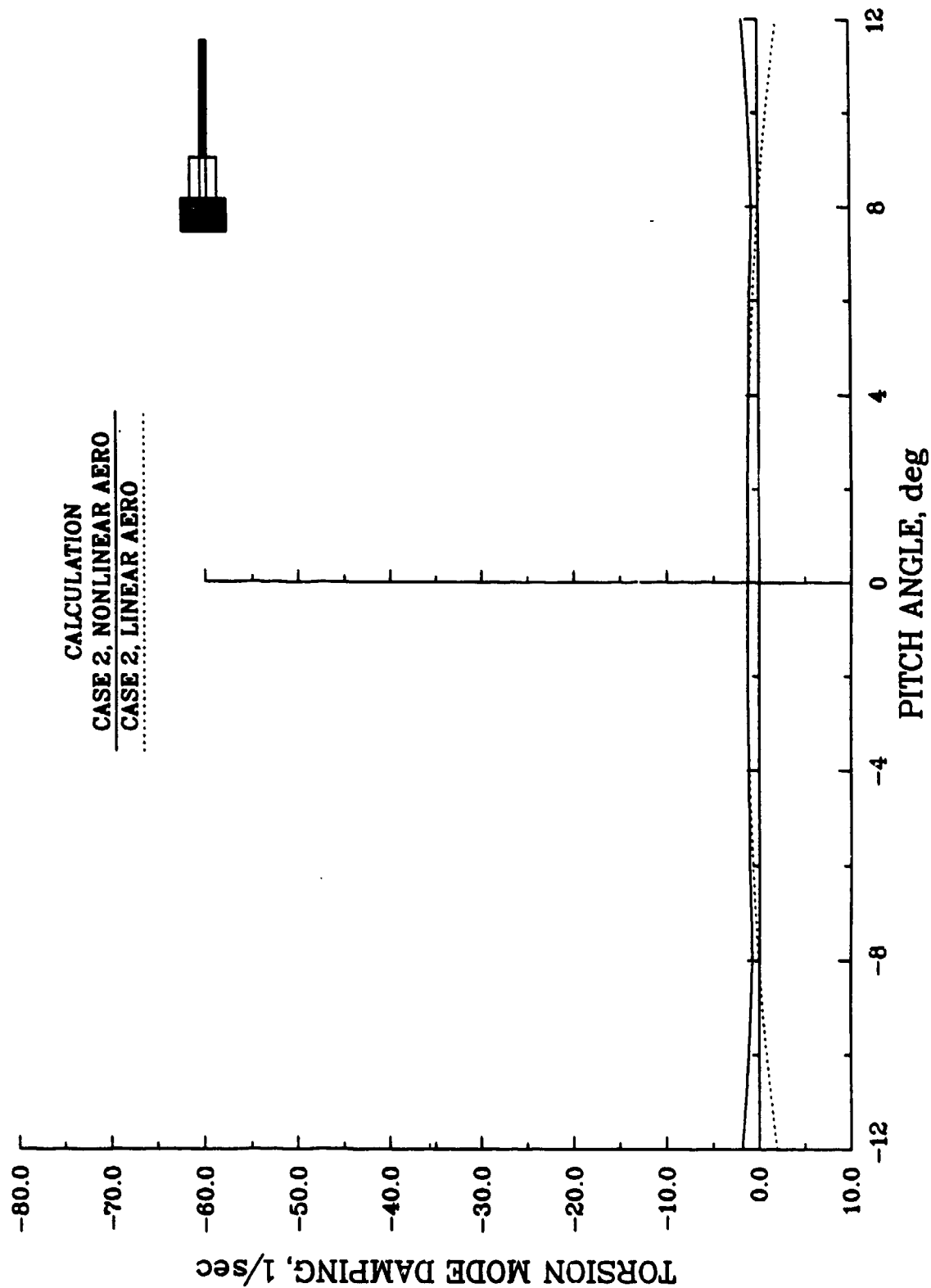
# LEAD-LAG MODE DAMPING TORSIONALLY SOFT ROTOR BOEING HELICOPTER



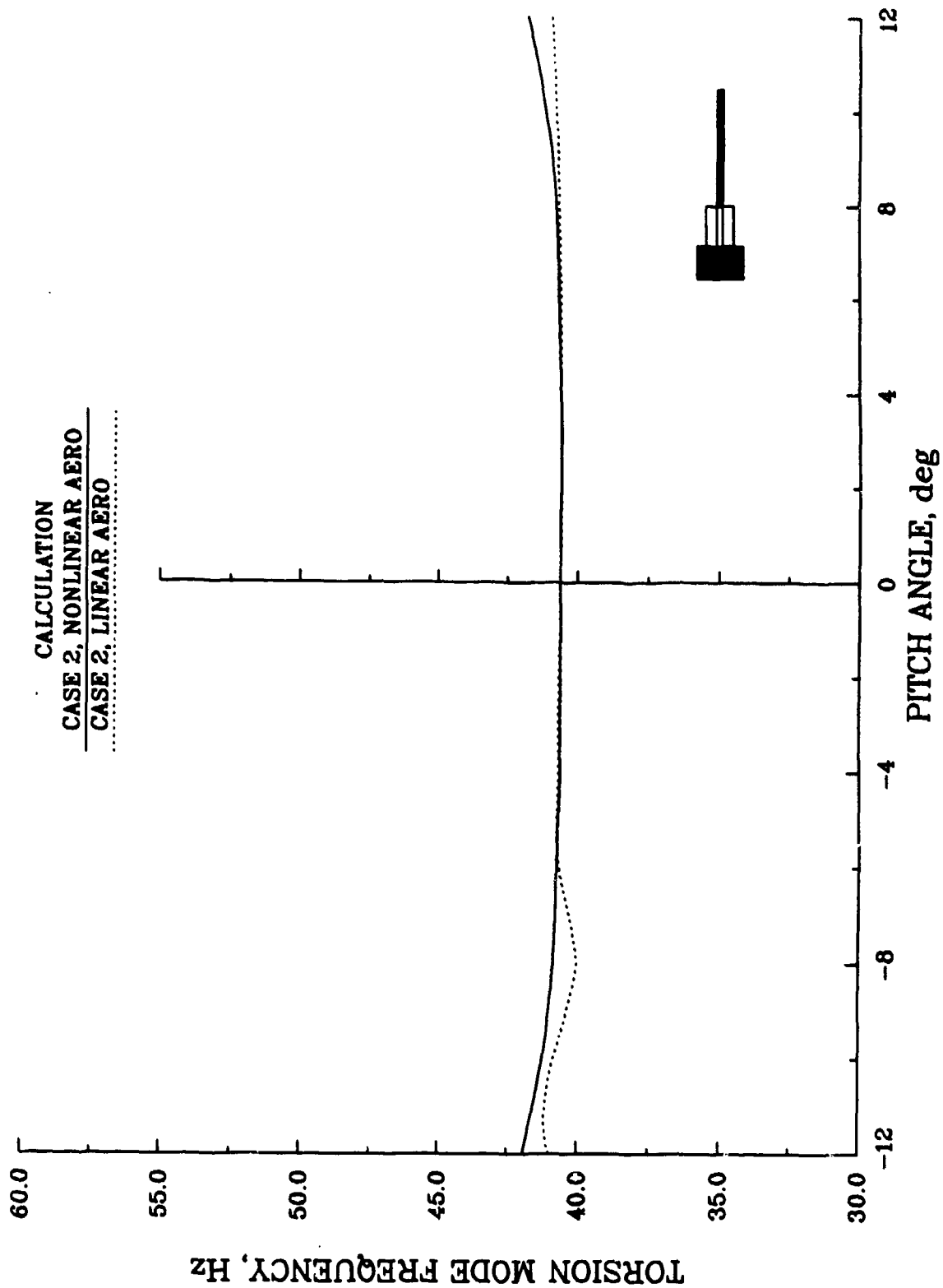
# LEAD-LAG MODE FREQUENCY TORSIONALLY SOFT ROTOR BOEING HELICOPTER



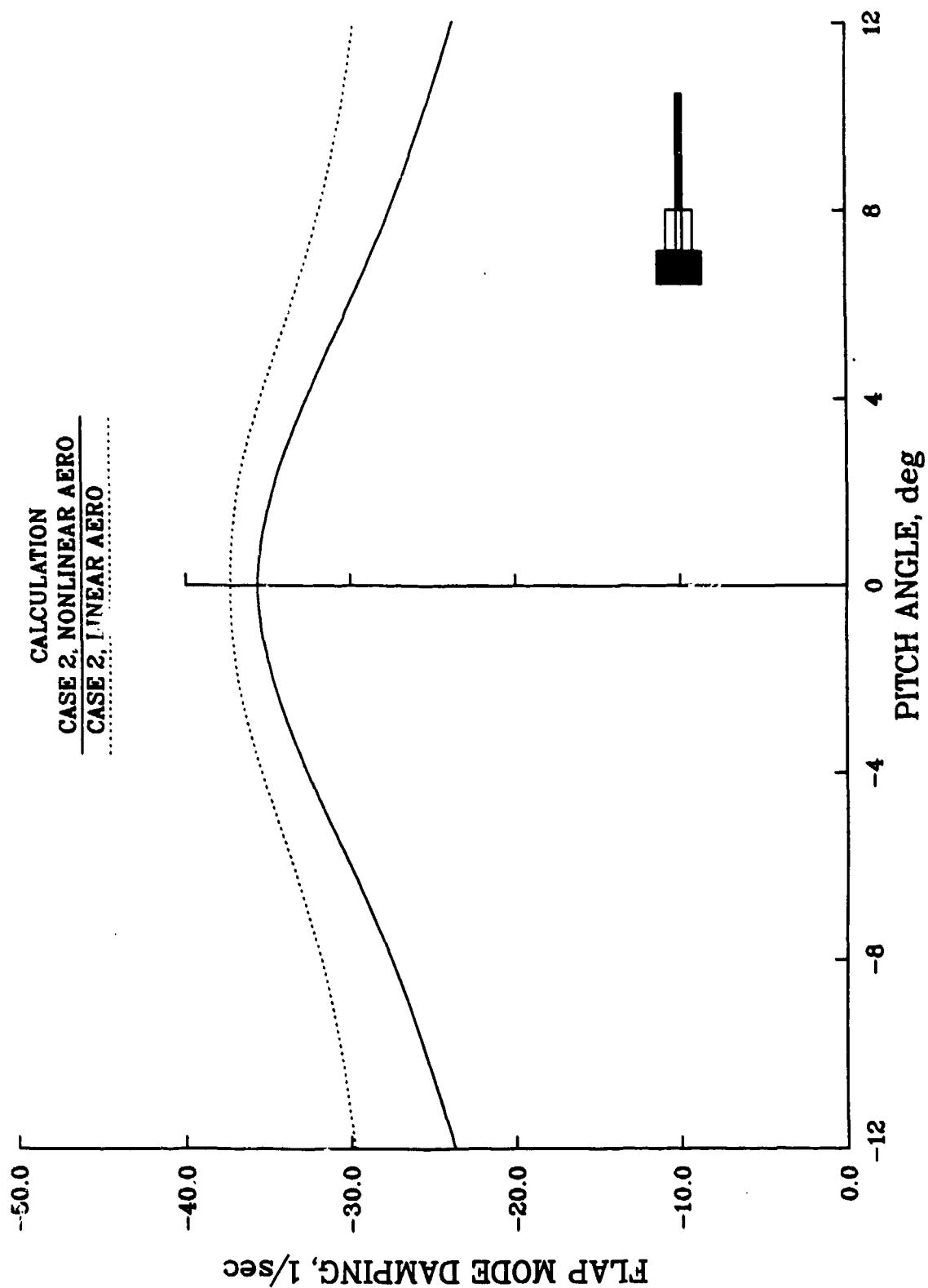
# TORSION MODE DAMPING TORSIONALLY SOFT ROTOR BOEING HELICOPTER



# TORSION MODE FREQUENCY TORSIONALLY SOFT ROTOR BOEING HELICOPTER

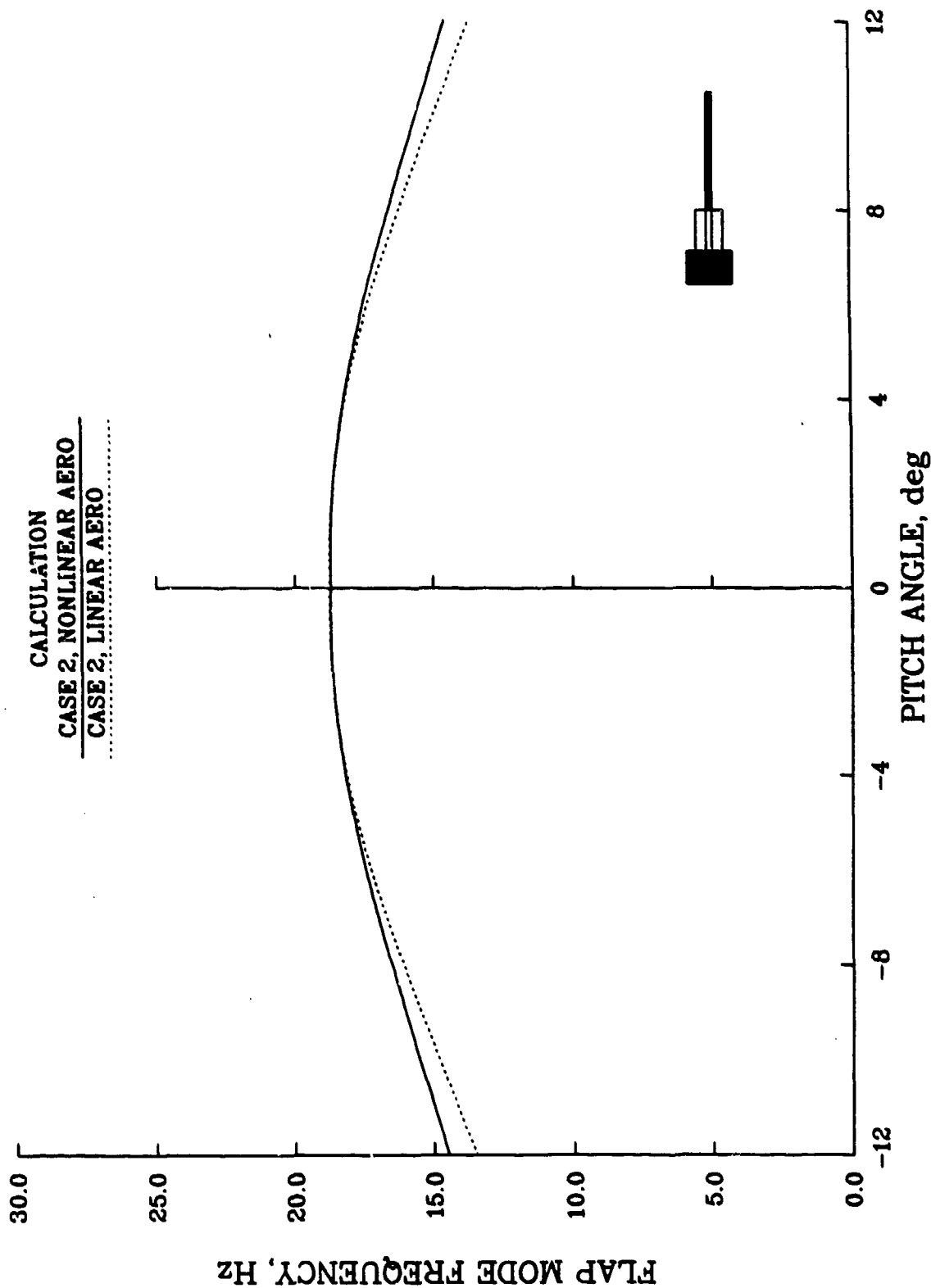


# FLAP MODE DAMPING TORSIONALLY SOFT ROTOR MCDONNELL DOUGLAS HELICOPTER

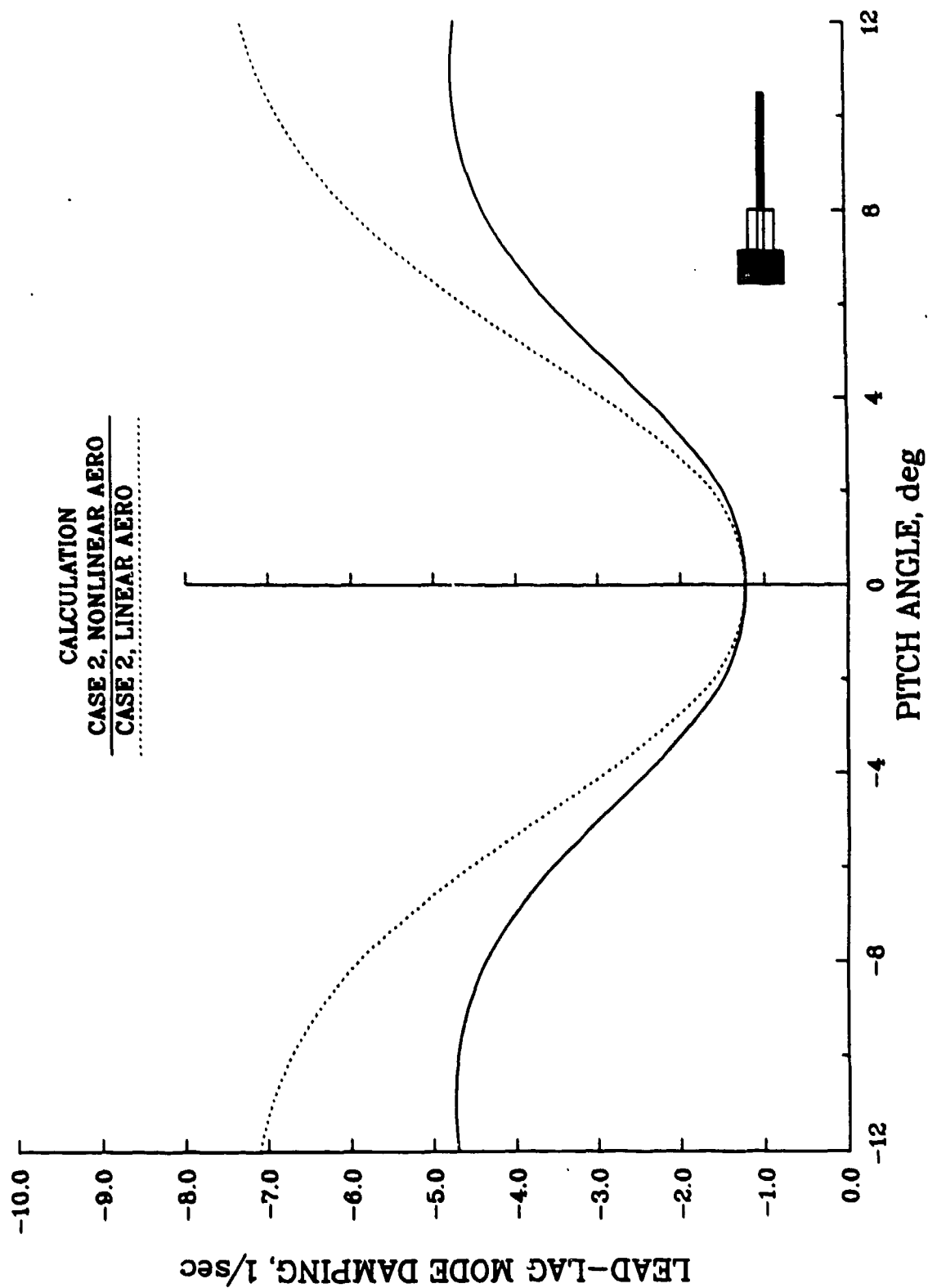




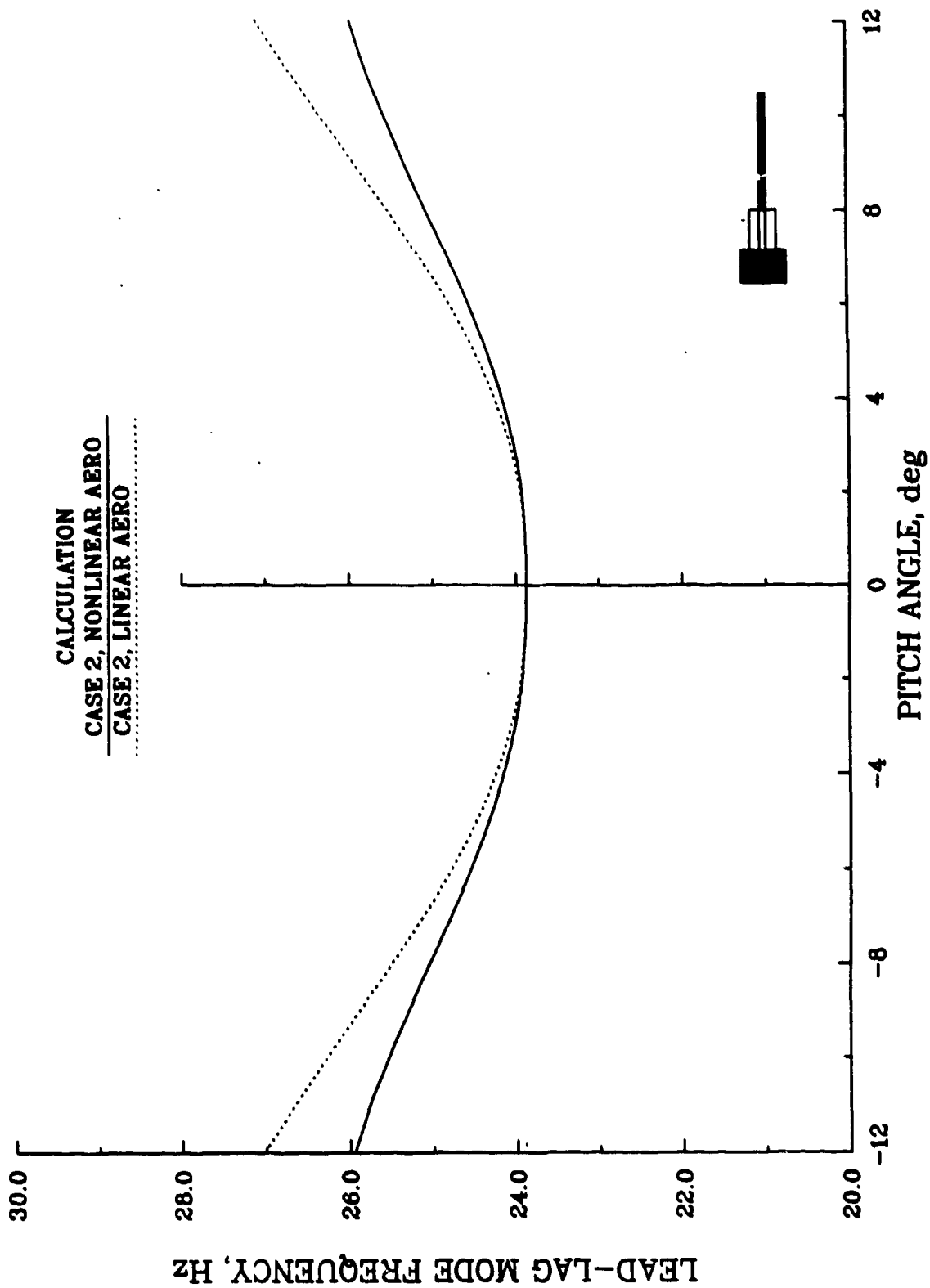
# FLAP MODE FREQUENCY TORSIONALLY SOFT ROTOR MCDONNELL DOUGLAS HELICOPTER



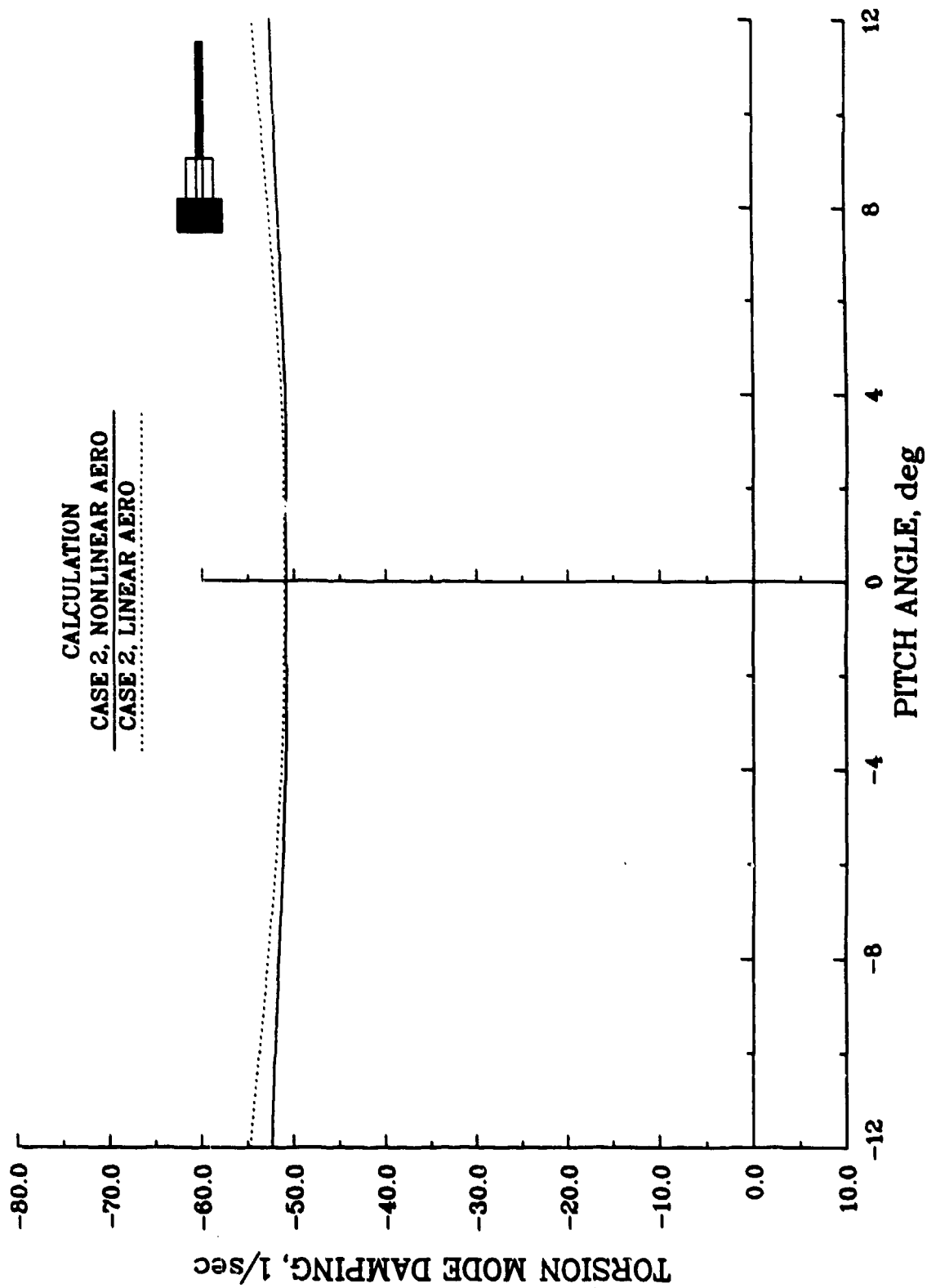
# LEAD-LAG MODE DAMPING TORSIONALLY SOFT ROTOR MCDONNELL DOUGLAS HELICOPTER



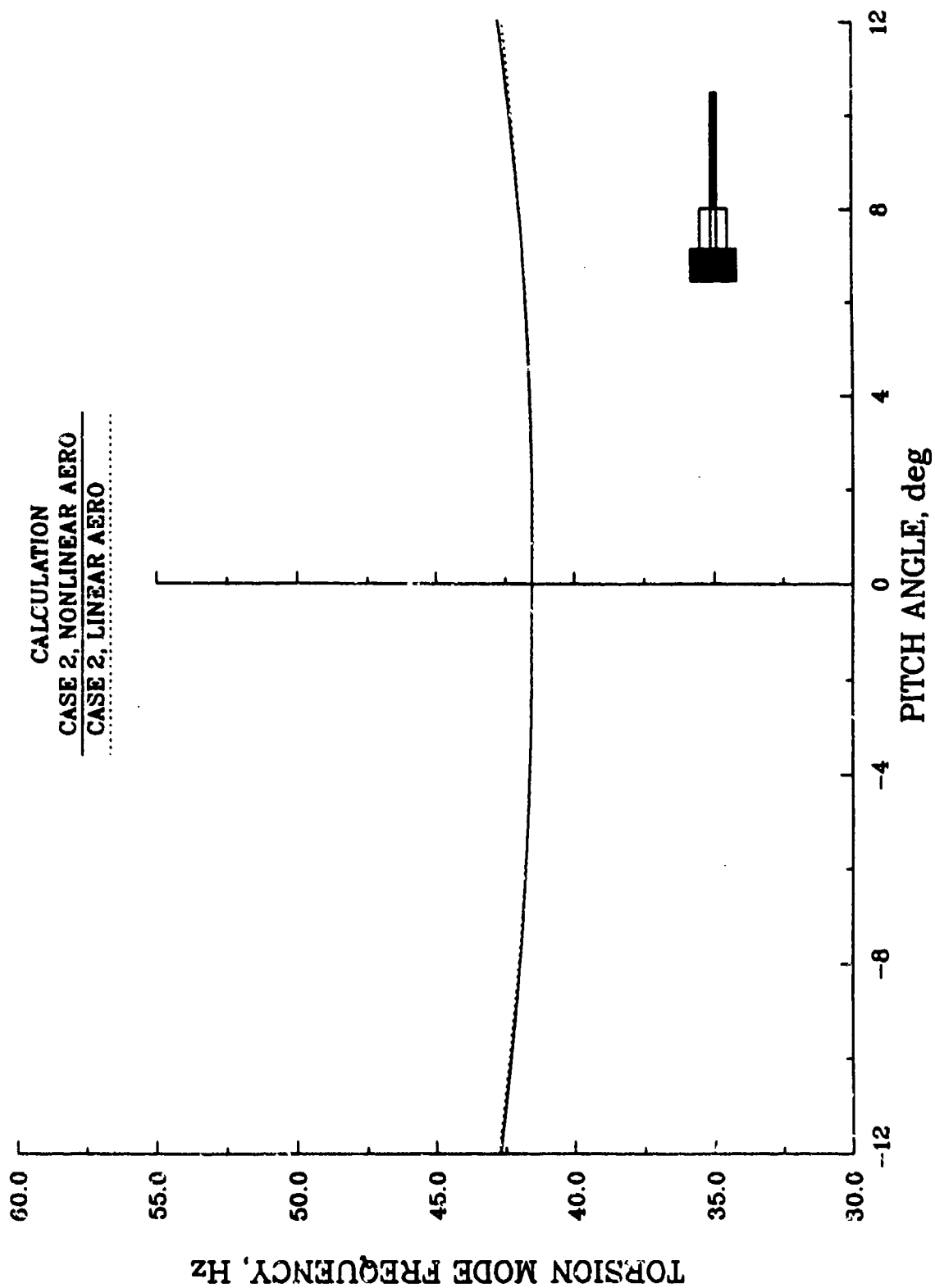
# LEAD-LAG MODE FREQUENCY TORSIONALLY SOFT ROTOR MCDONNELL DOUGLAS HELICOPTER



# TORSION MODE DAMPING TORSIONALLY SOFT ROTOR MCDONNELL DOUGLAS HELICOPTER

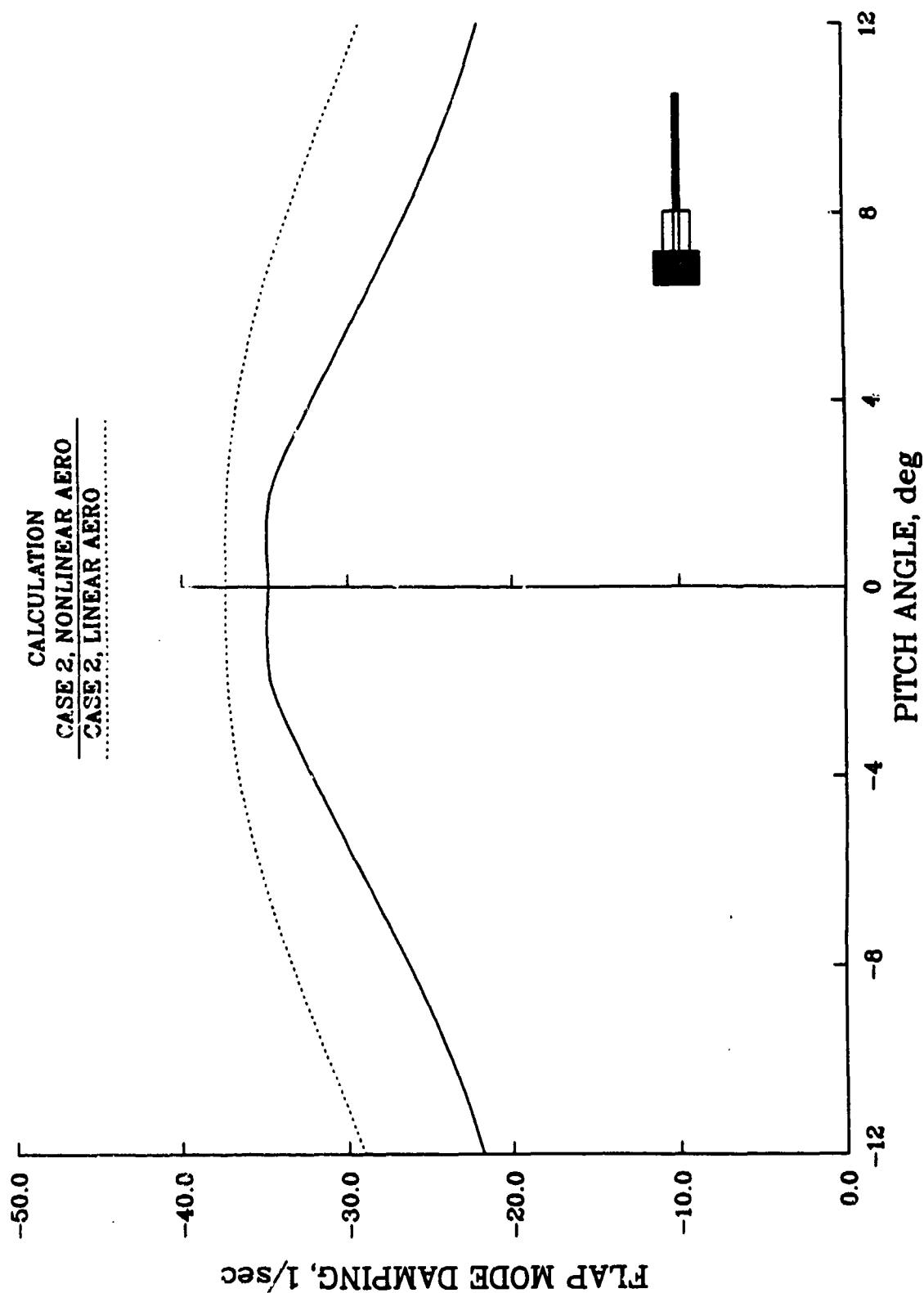


# TORSION MODE FREQUENCY TORSIONALLY SOFT ROTOR MCDONNELL DOUGLAS HELICOPTER



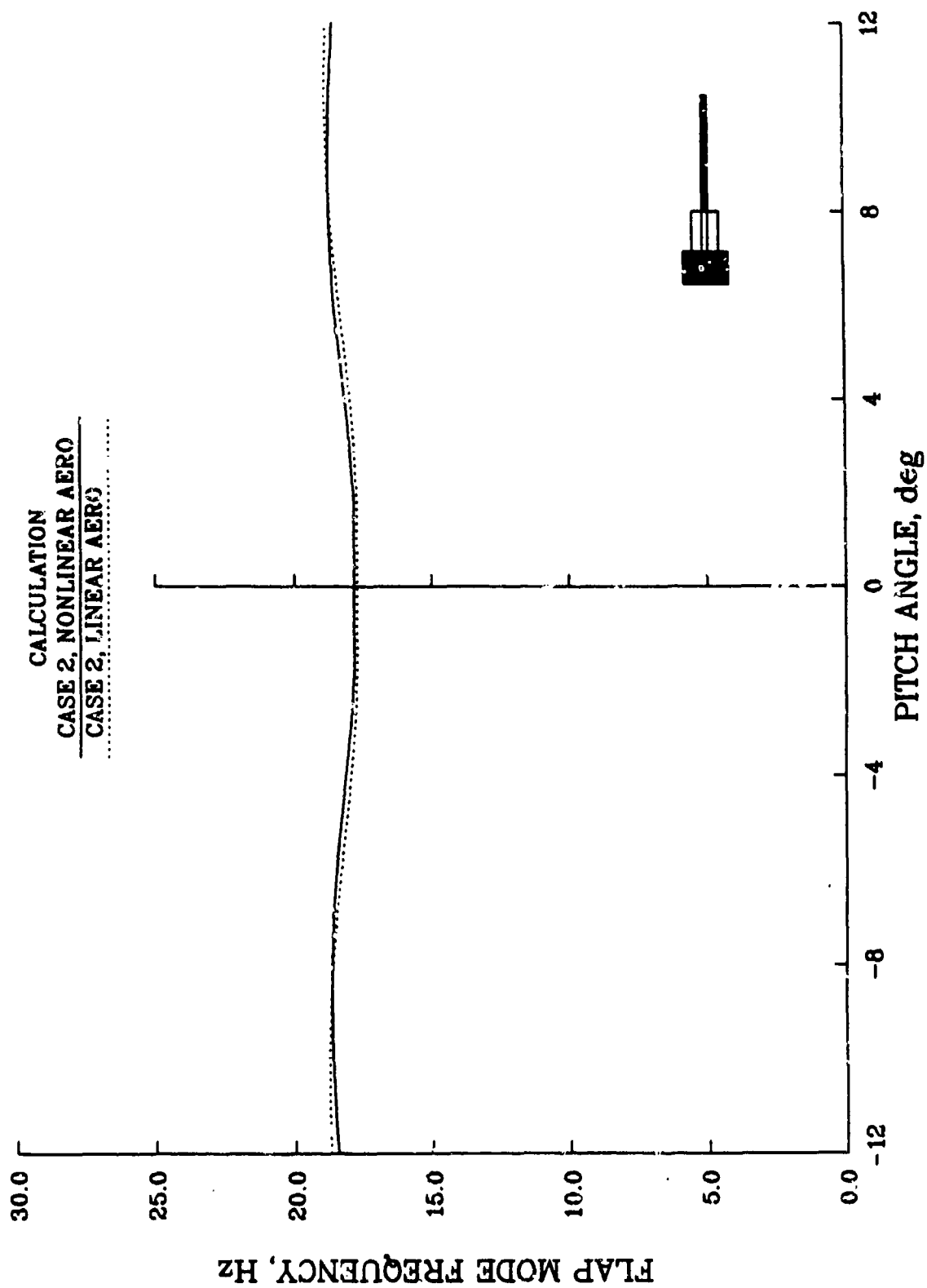
# FLAP MODE DAMPING TORSIONALLY SOFT ROTOR SIKORSKY AIRCRAFT

CALCULATION  
CASE 2, NONLINEAR AERO  
CASE 2, LINEAR AERO



# FLAP MODE FREQUENCY TORSIONALLY SOFT ROTOR SIKORSKY AIRCRAFT

**CALCULATION**  
**CASE 2, NONLINEAR AERO**  
**CASE 2, LINEAR AERO**

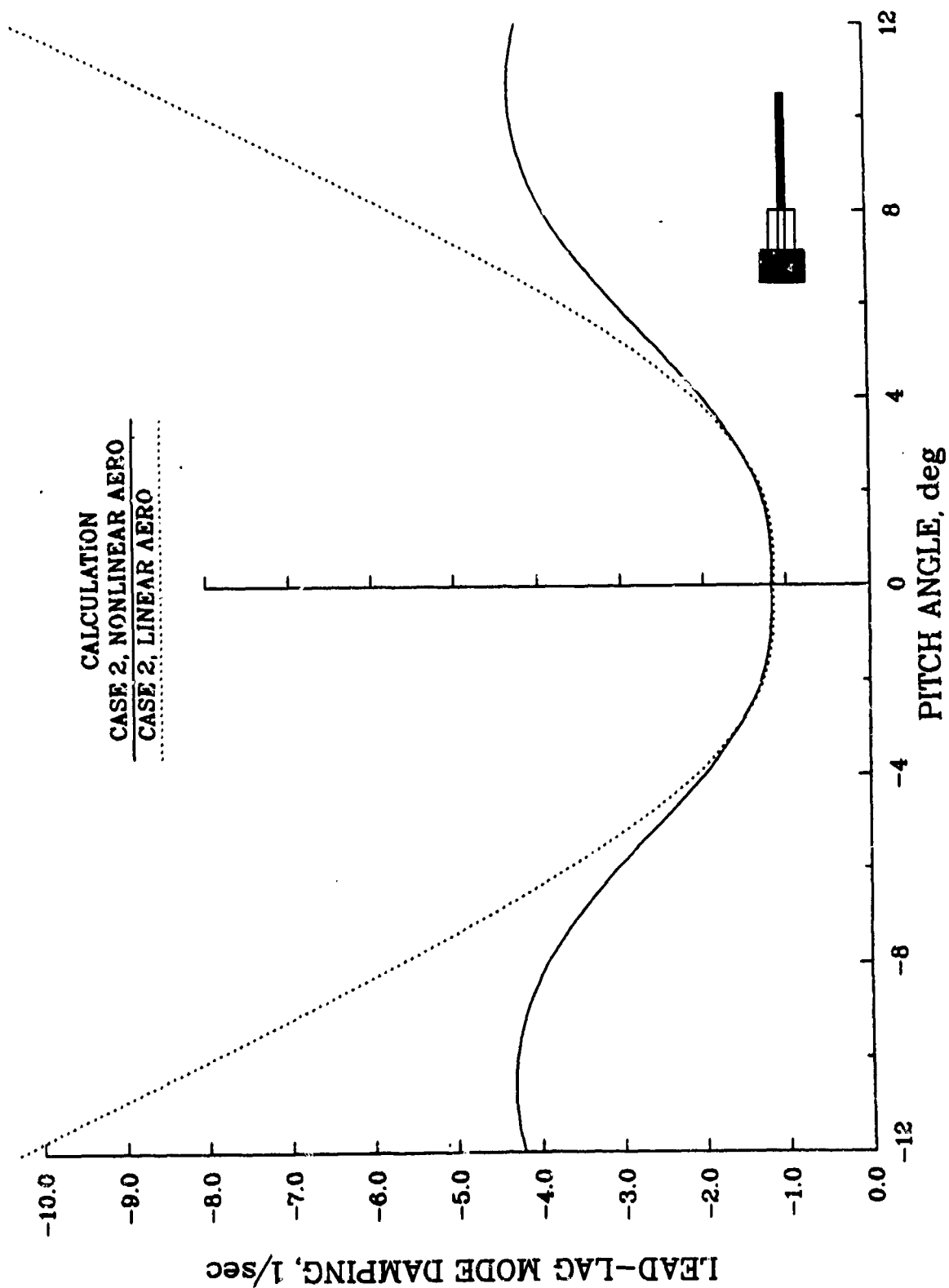


# LEAD-LAG MODE DAMPING TORSIONALLY SOFT ROTOR SIKORSKY AIRCRAFT

CALCULATION

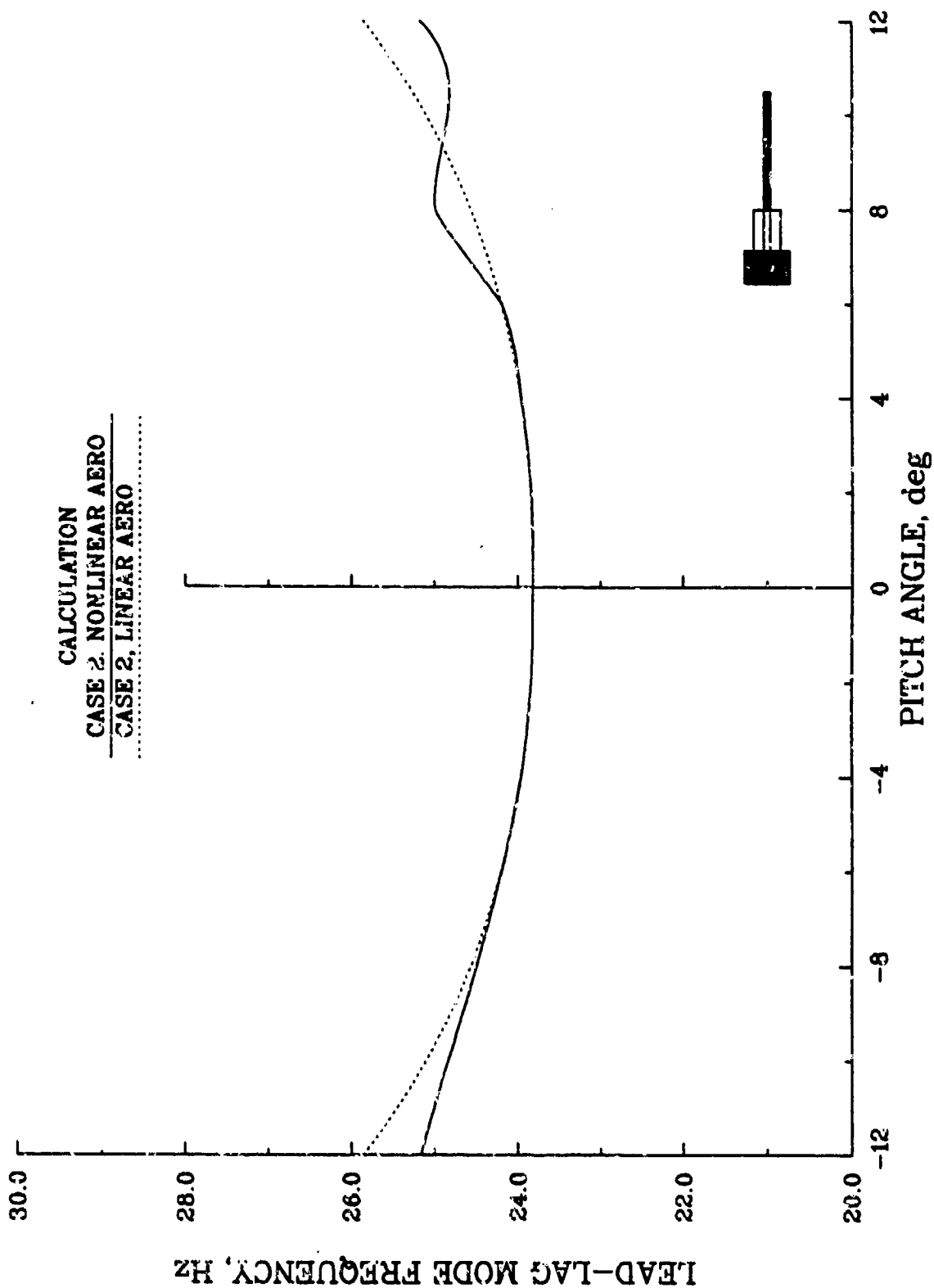
CASE 2, NONLINEAR AERO

CASE 2, LINEAR AERO

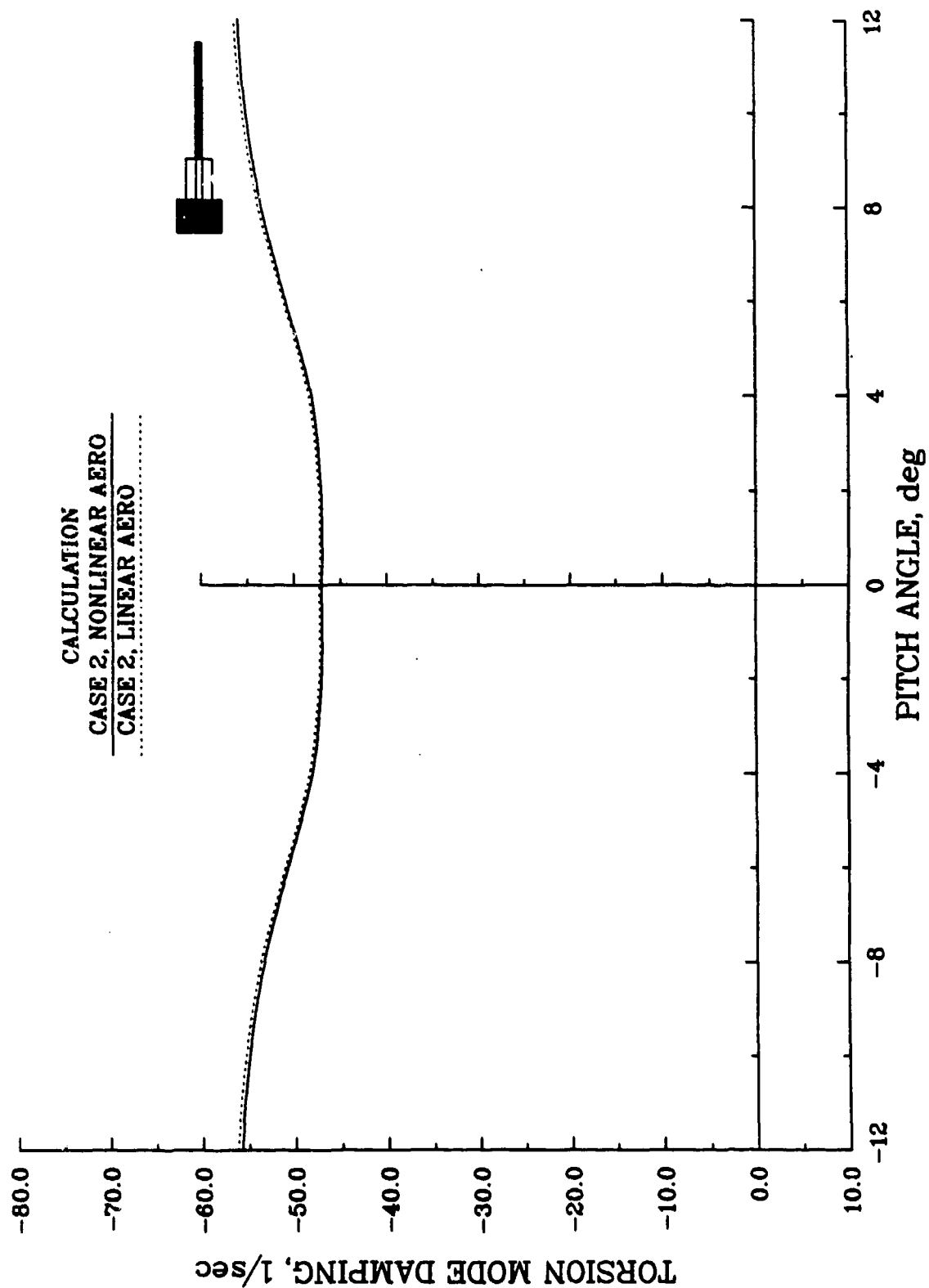




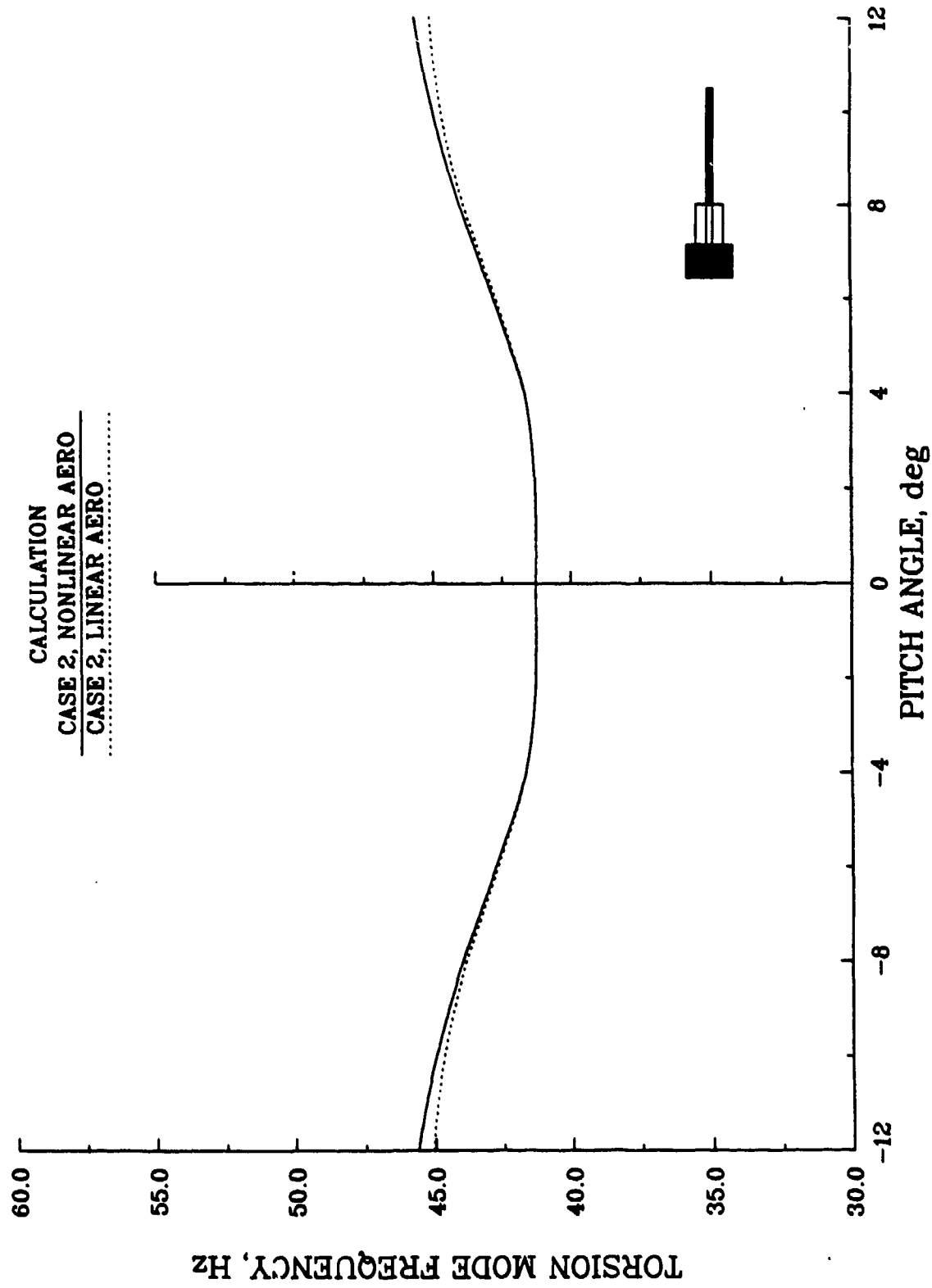
# LEAD-LAG MODE FREQUENCY TORSIONALLY SOFT ROTOR SIKORSKY AIRCRAFT



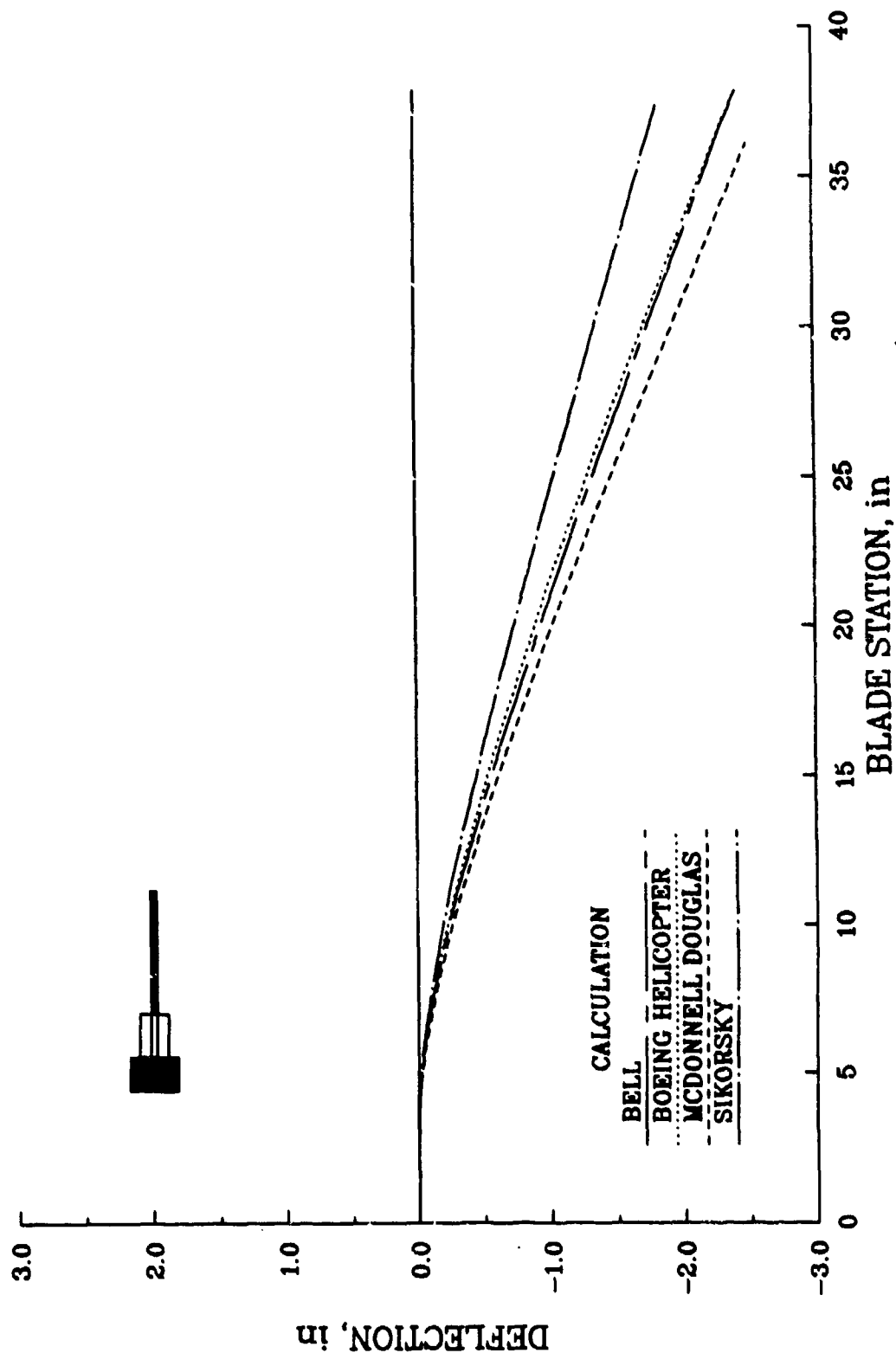
# TORSION MODE DAMPING TORSIONALLY SOFT ROTOR SIKORSKY AIRCRAFT



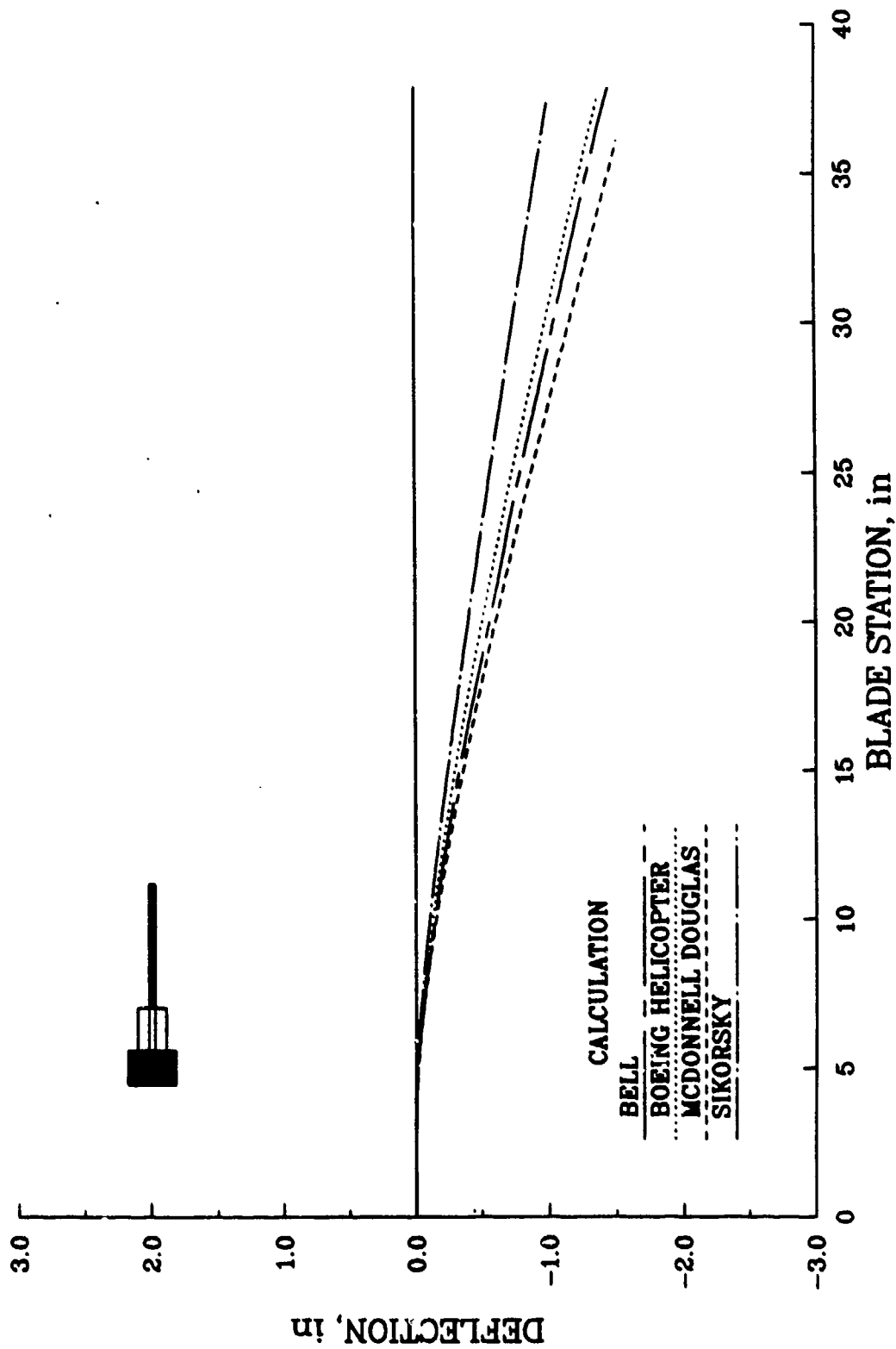
TORSION MODE FREQUENCY  
TORSIONALLY SOFT ROTOR  
SIKORSKY AIRCRAFT



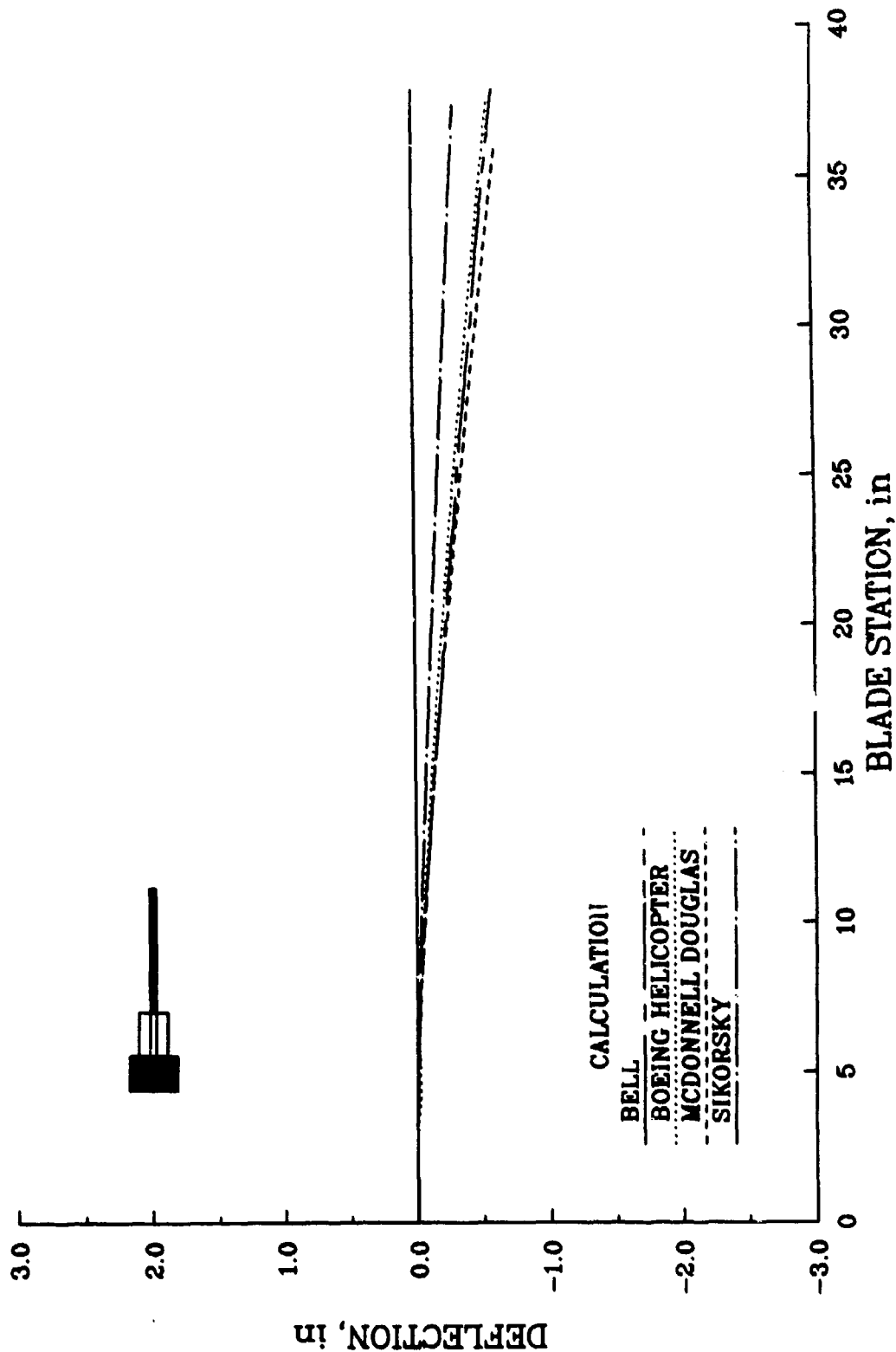
FLAP EQUILIBRIUM DEFLECTION - TASK 86e  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 2 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = -12 deg



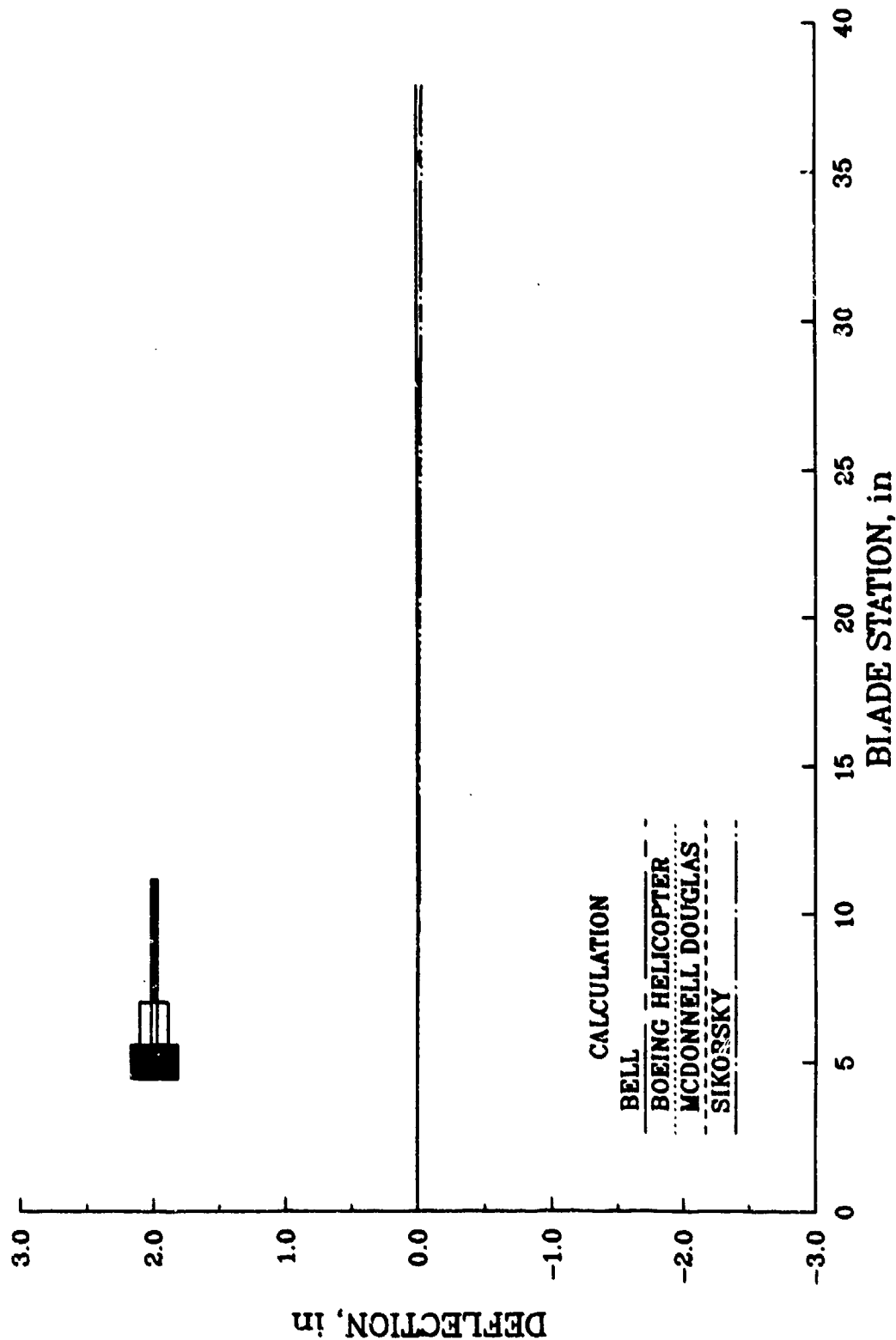
FLAP EQUILIBRIUM DEFLECTION - TASK 86e  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 2 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = -8 deg



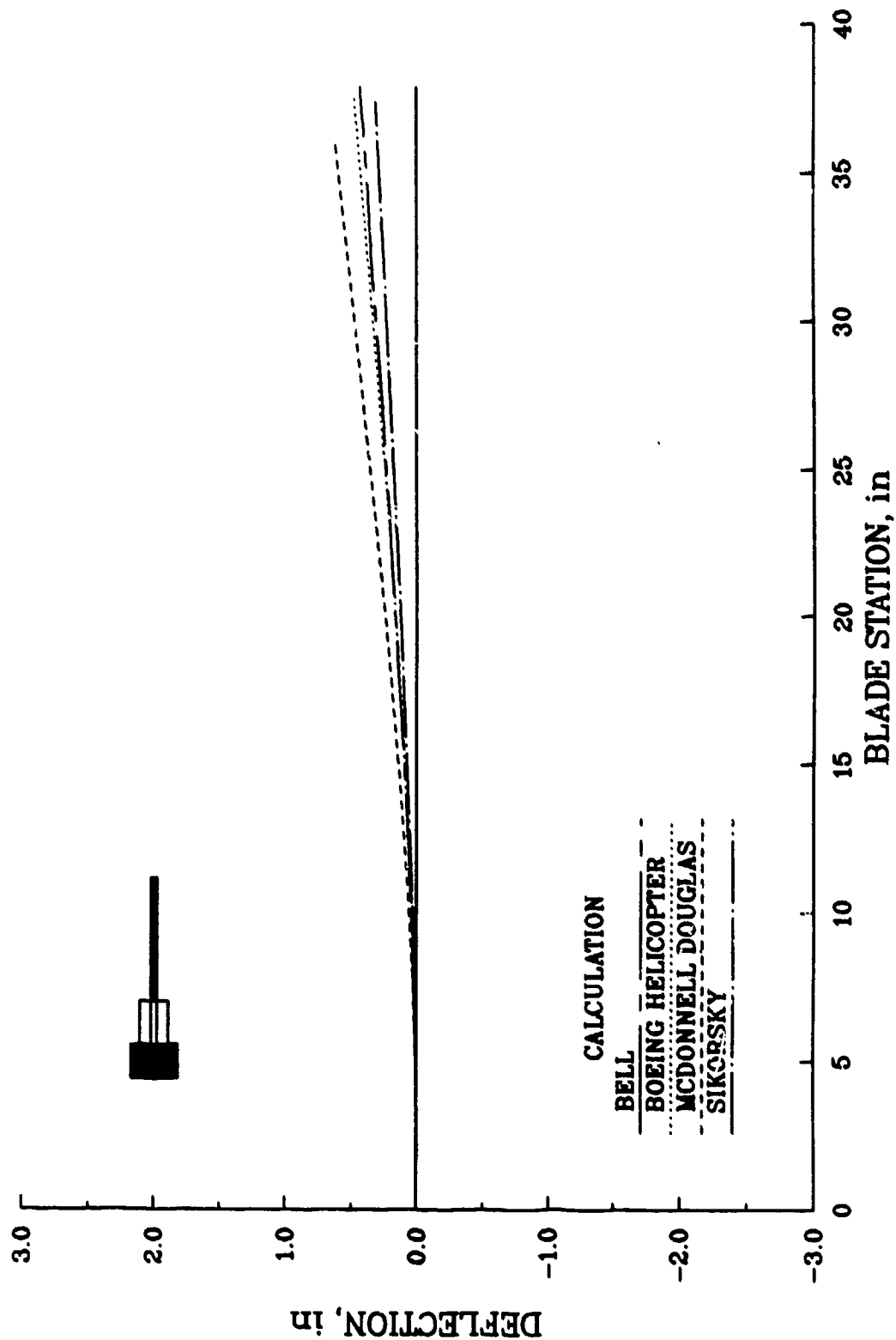
FLAP EQUILIBRIUM DEFLECTION - TASK 86e  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 2 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = -4 deg



FLAP EQUILIBRIUM DEFLECTION - TASK 88e  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 2 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = 0 deg

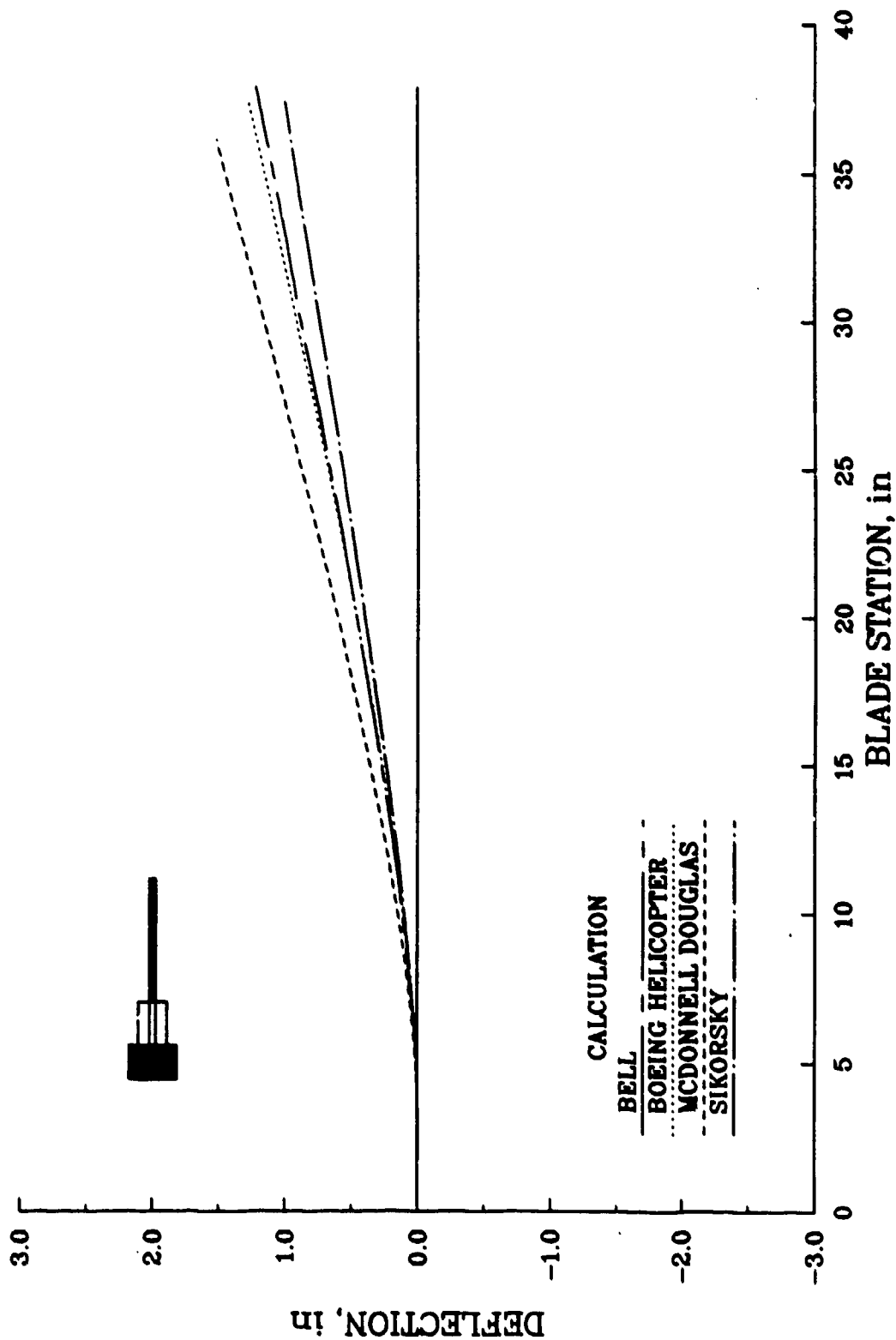


FLAP EQUILIBRIUM DEFLECTION - TASK 86e  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 2 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = 4 deg

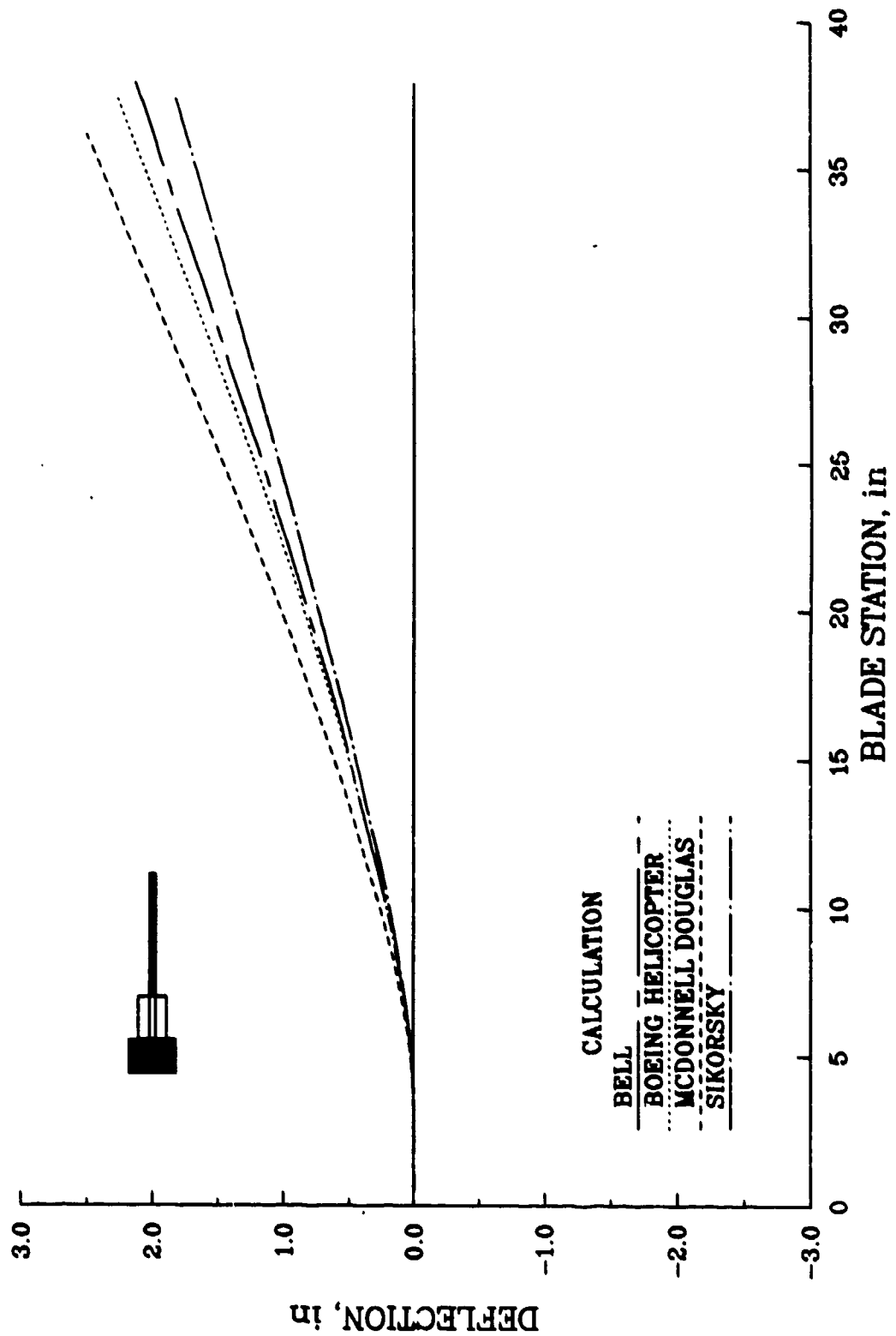




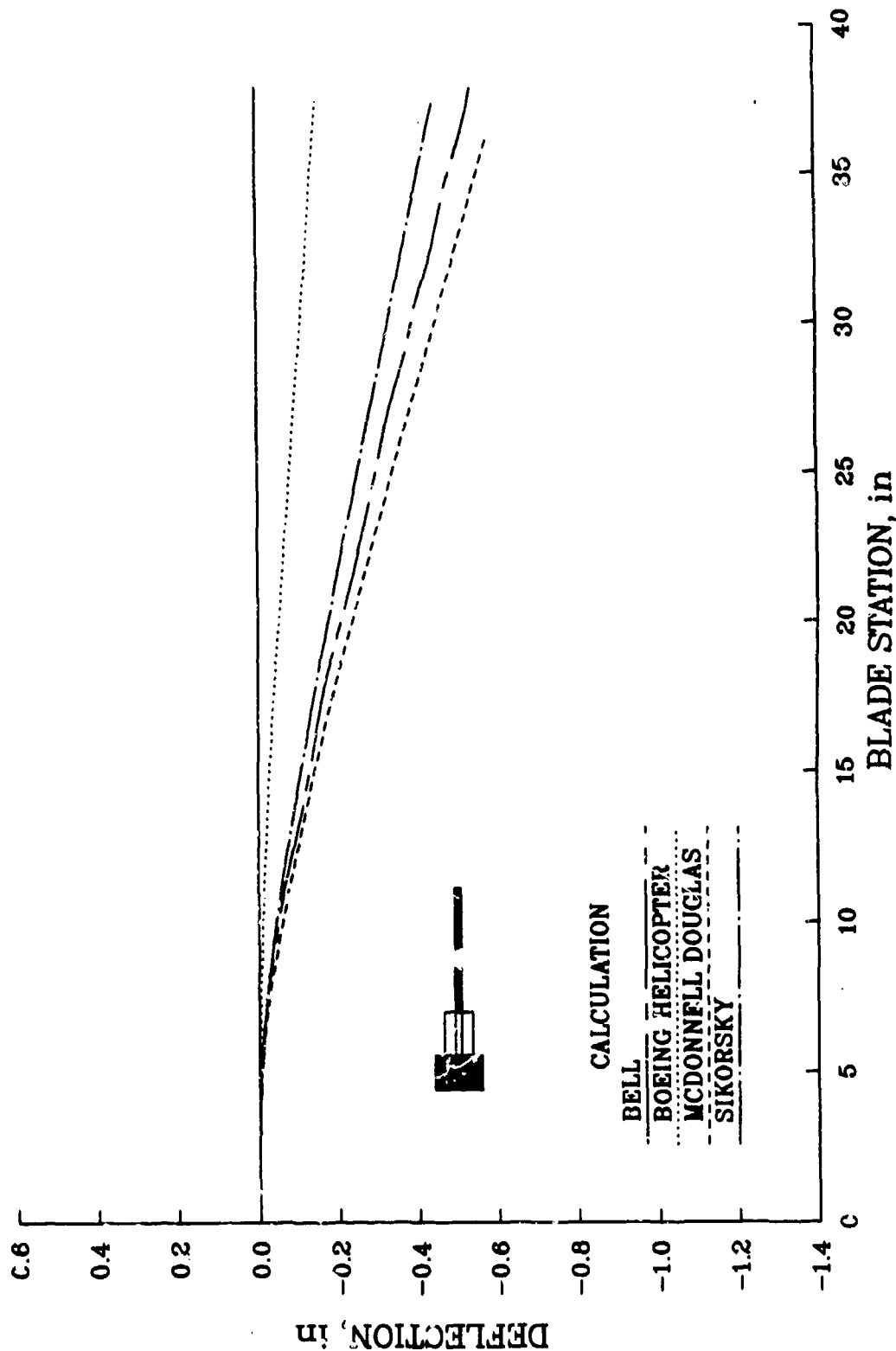
FLAP EQUILIBRIUM DEFLECTION - TASK 86e  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 2 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = 8 deg



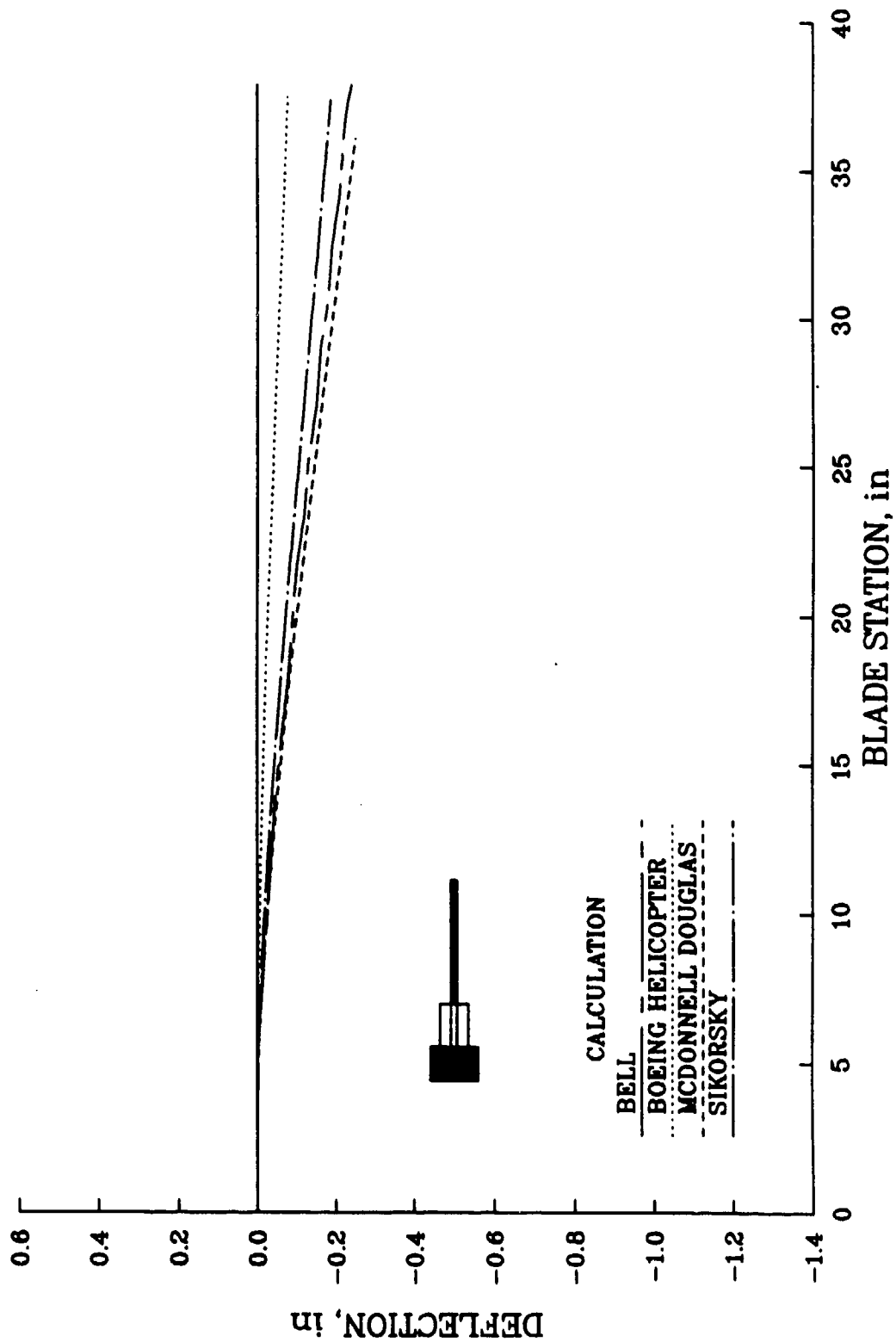
FLAP EQUILIBRIUM DEFLECTION - TASK 86e  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 2 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = 12 deg



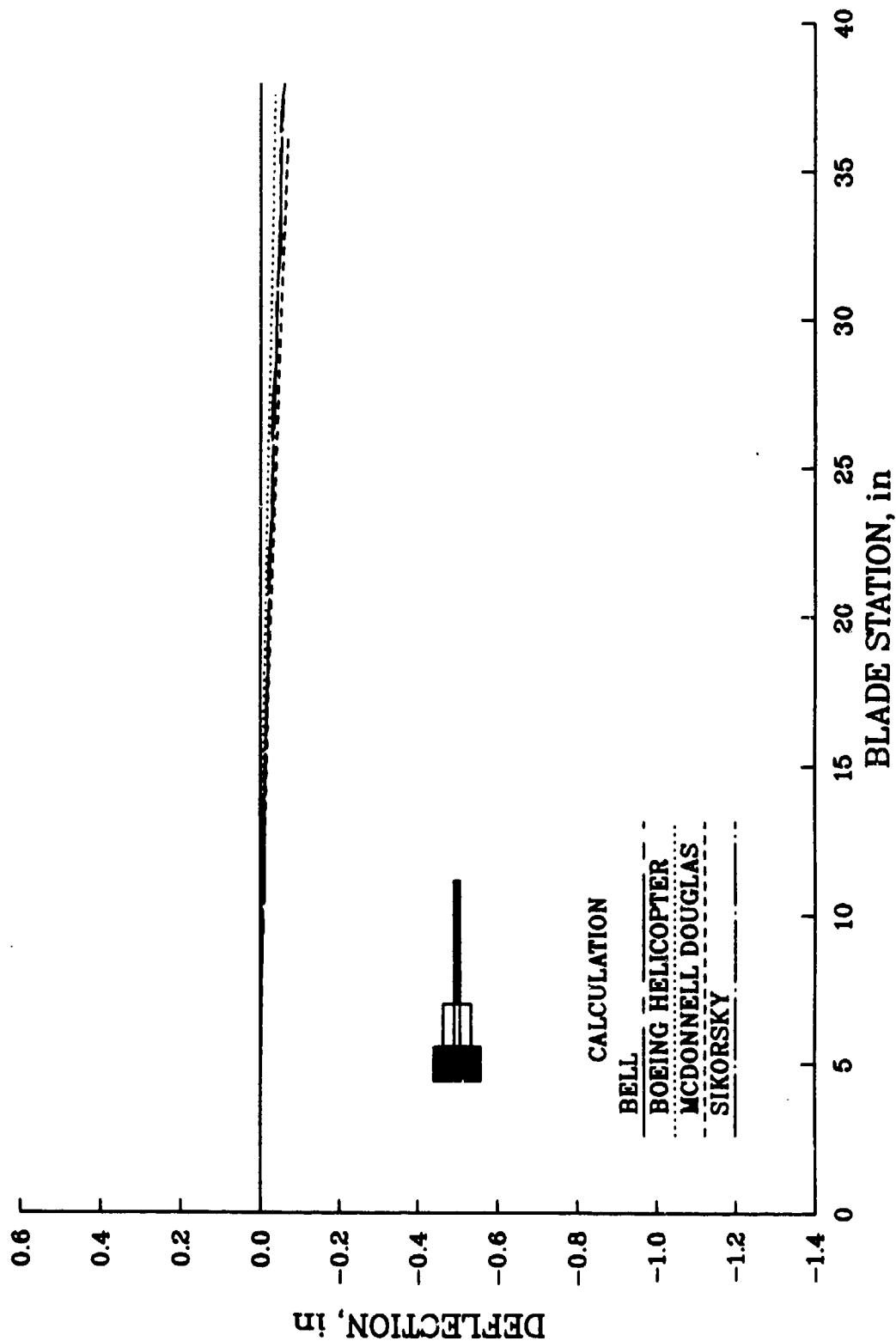
LEAD-LAG EQUILIBRIUM DEFLECTION - TASK 86e  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 2 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = -12 deg



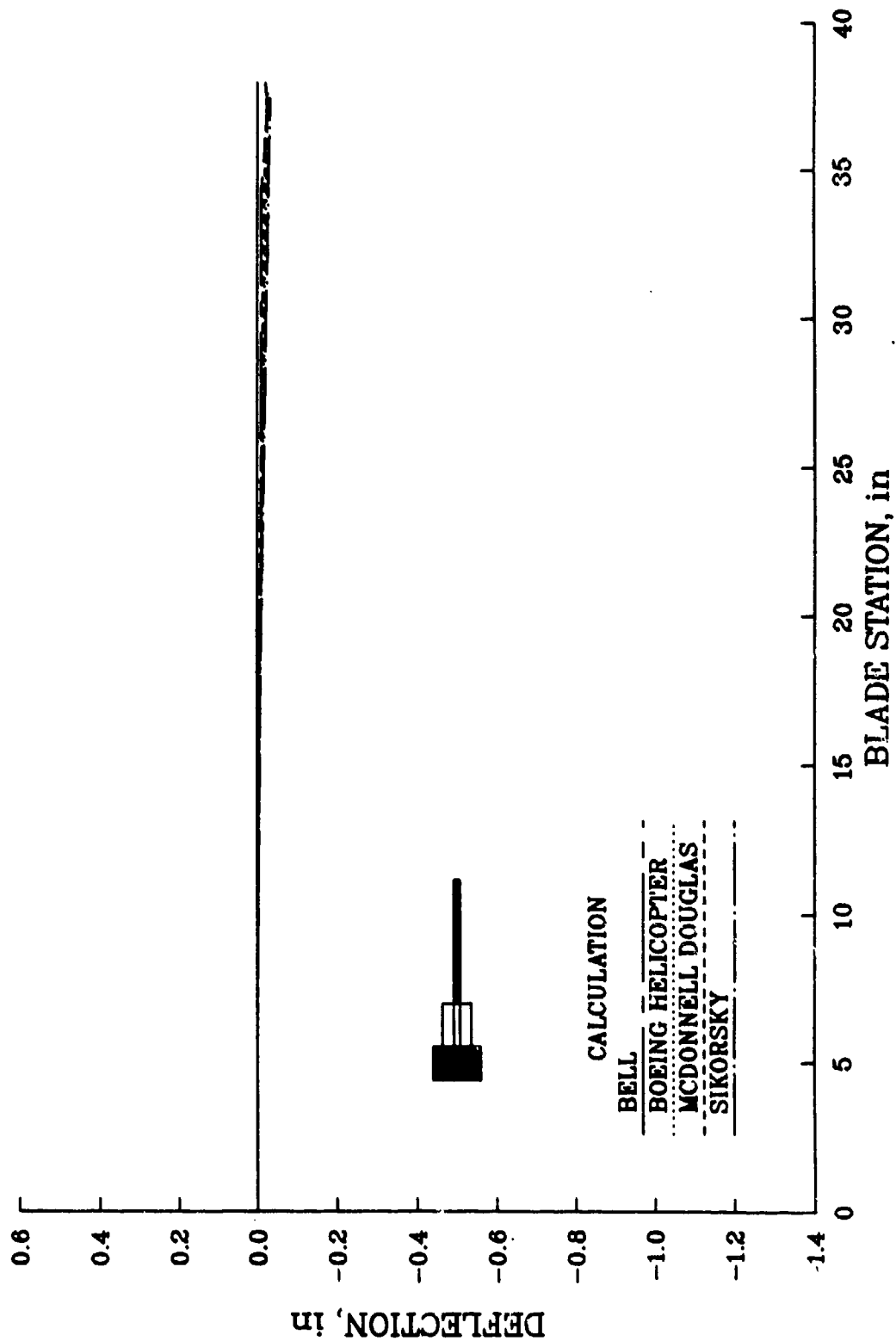
LEAD-LAG EQUILIBRIUM DEFLECTION - TASK 86e  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 2 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = -8 deg



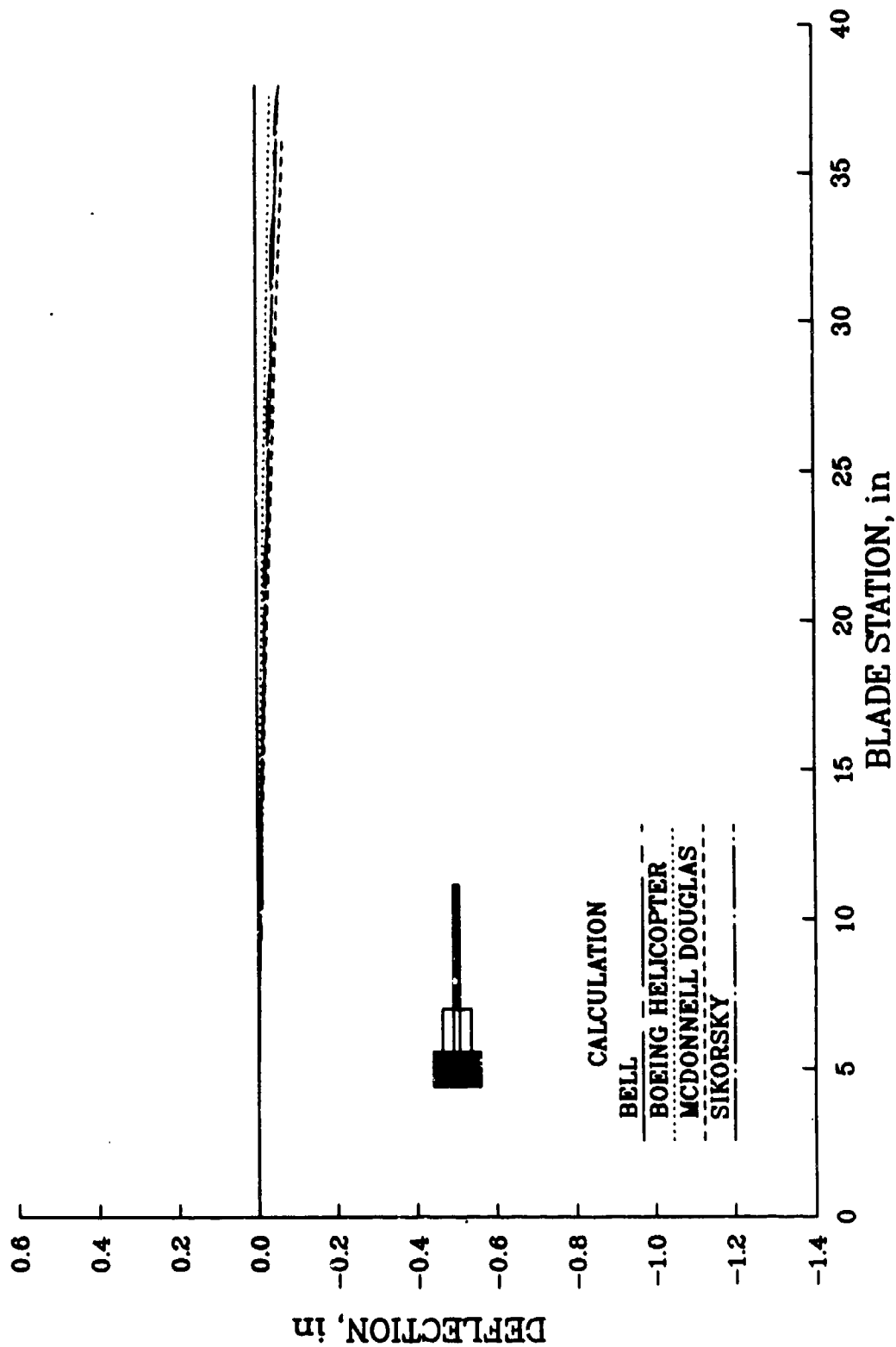
LEAD-LAG EQUILIBRIUM DEFLECTION - TASK 86e  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 2 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = -4 deg



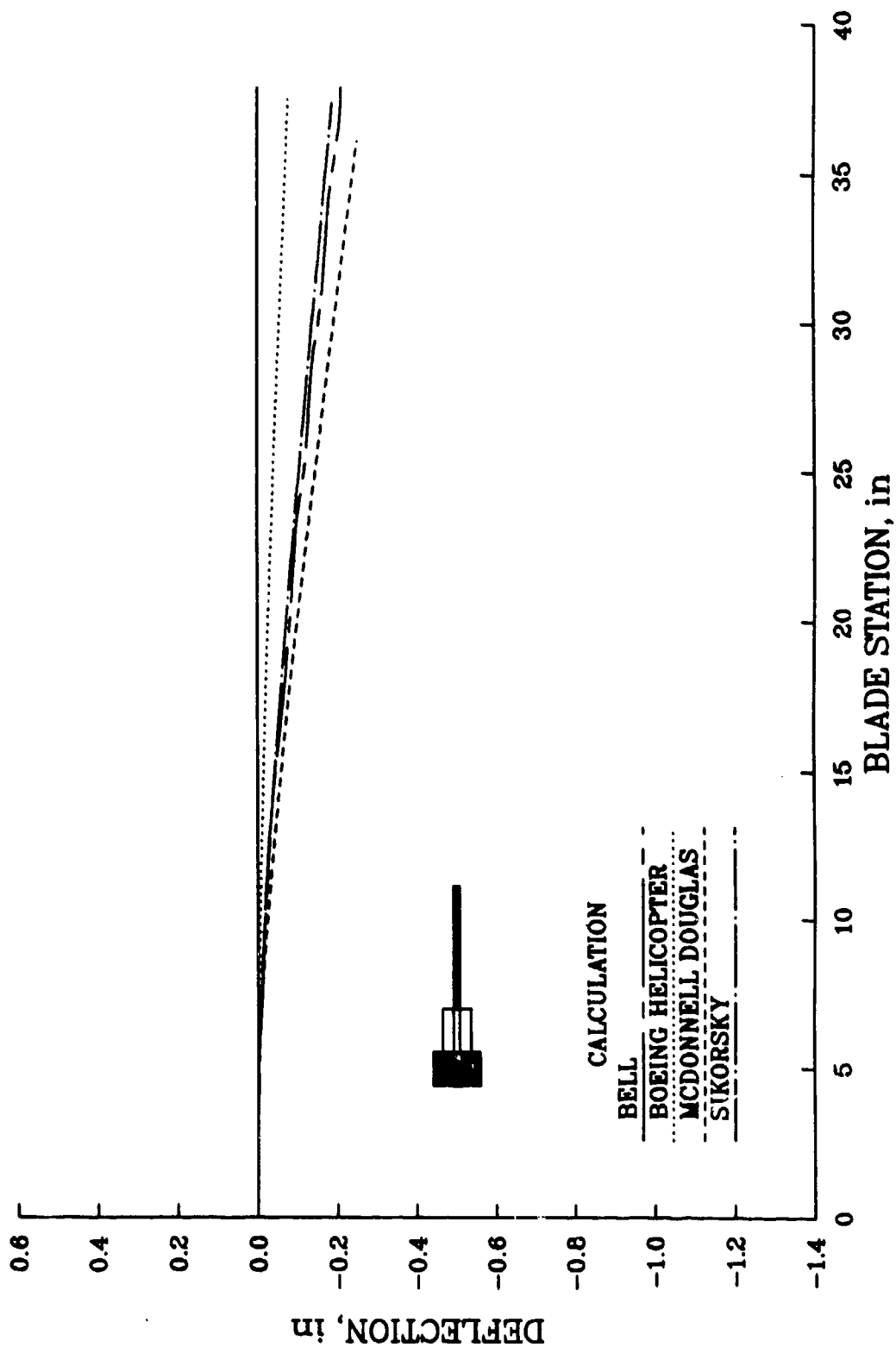
LEAD-LAG EQUILIBRIUM DEFLECTION - TASK 86e  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 2 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = 0 deg



LEAD-LAG EQUILIBRIUM DEFLECTION - TASK 86e  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 2 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = 4 deg

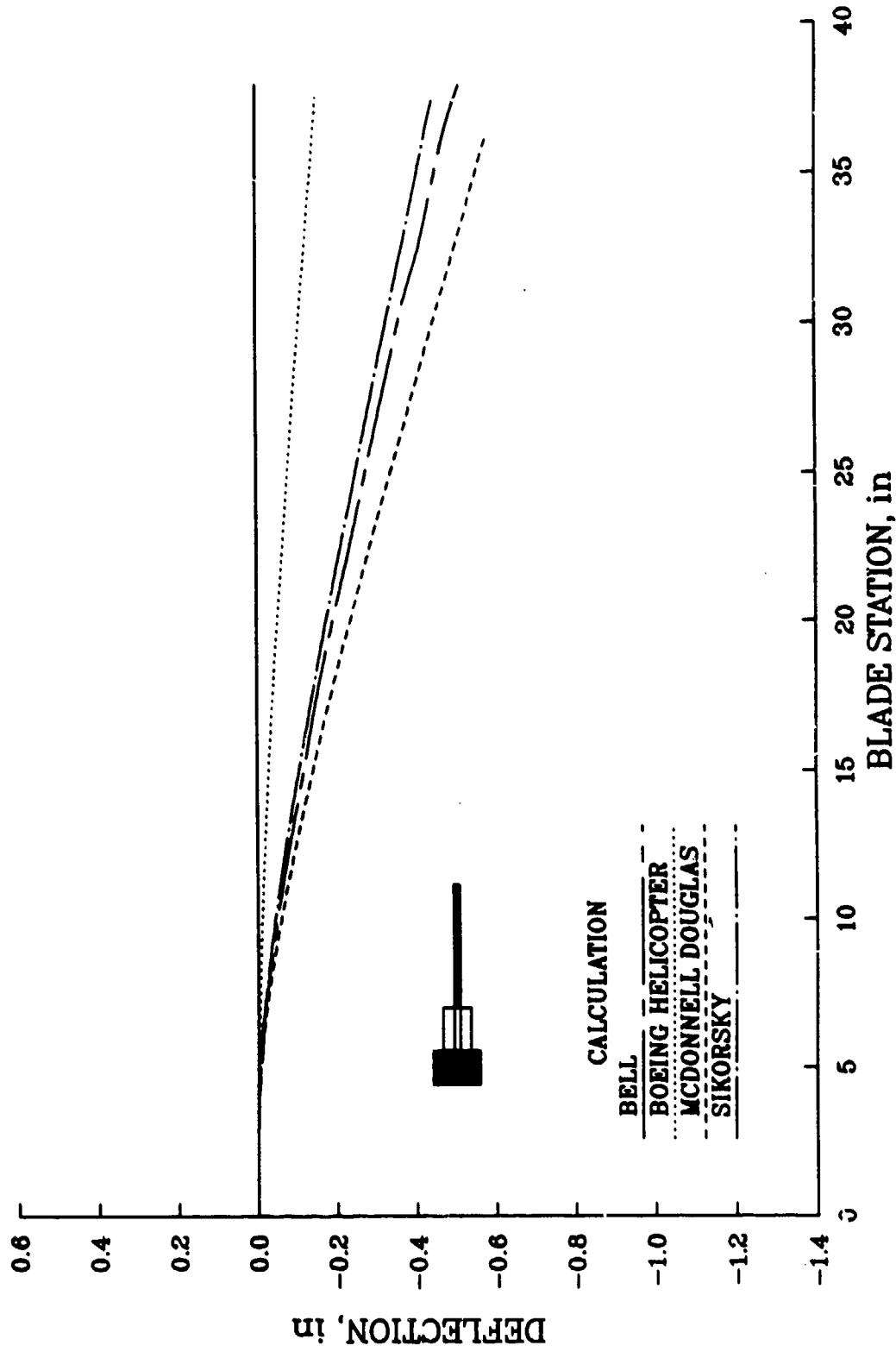


LEAD-LAG EQUILIBRIUM DEFLECTION -- TASK 86e  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 2 -- TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = 8 deg

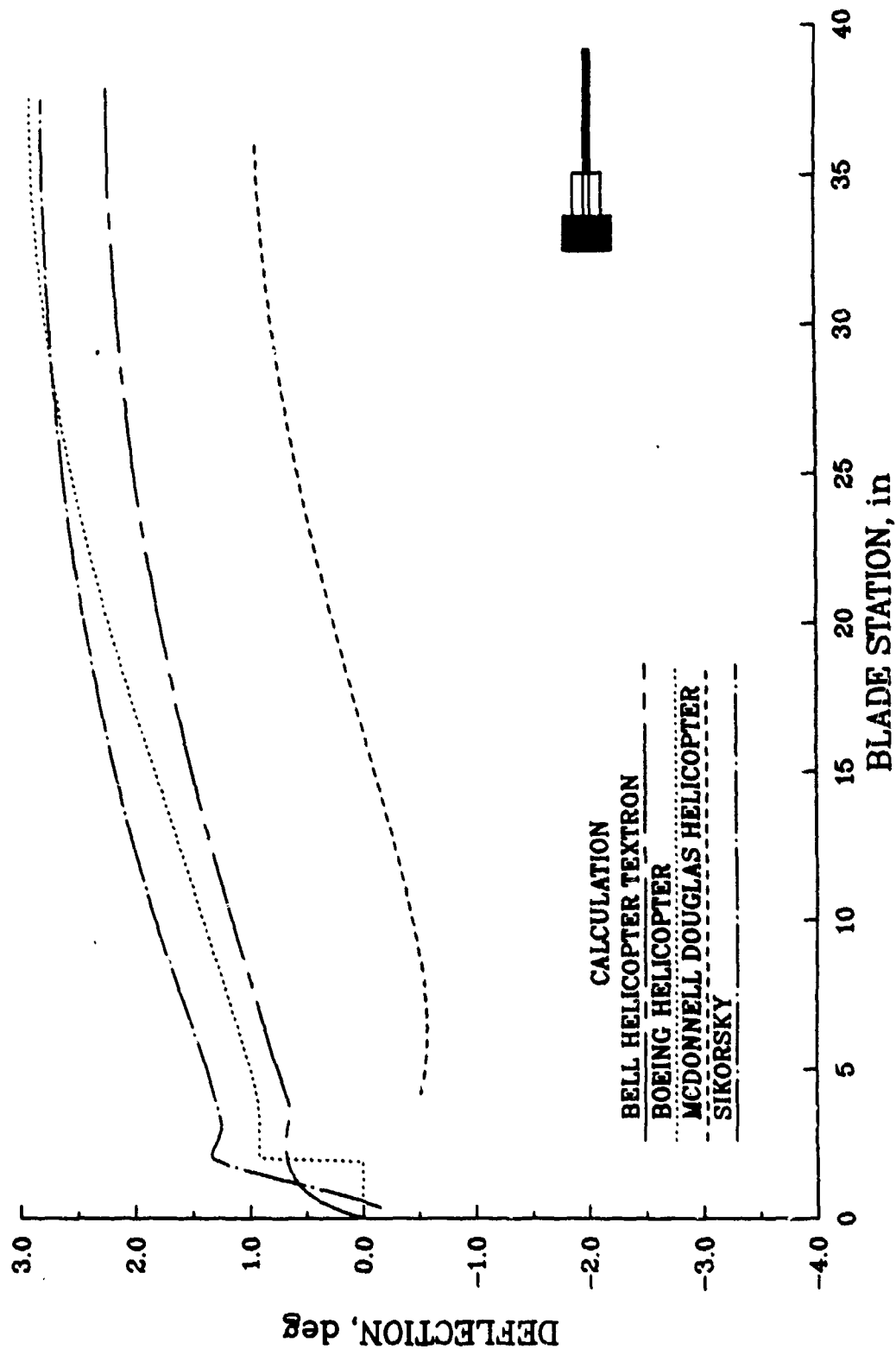




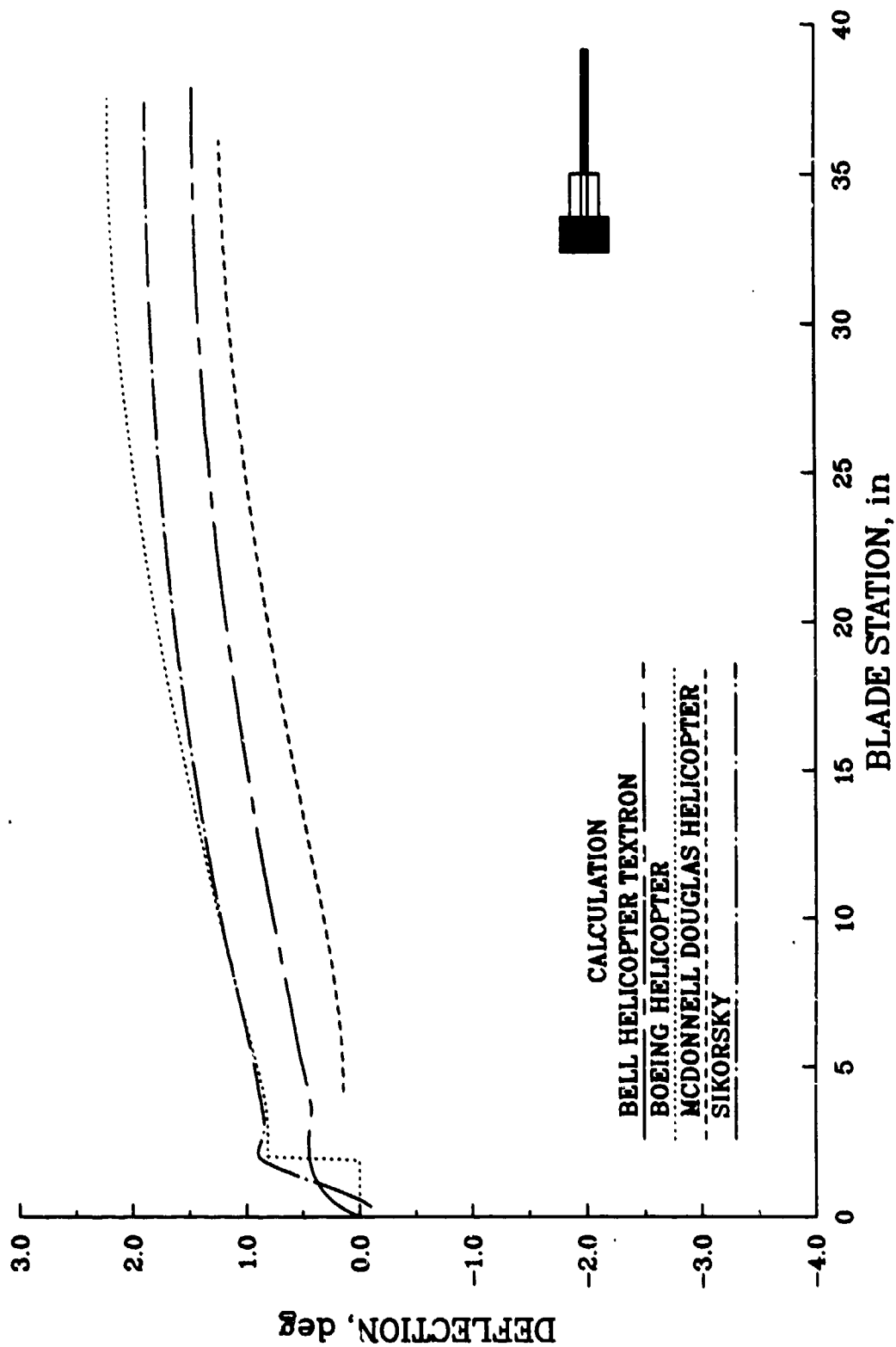
LEAD-LAG EQUILIBRIUM DEFLECTION - TASK 86e  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 2 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = 12 deg



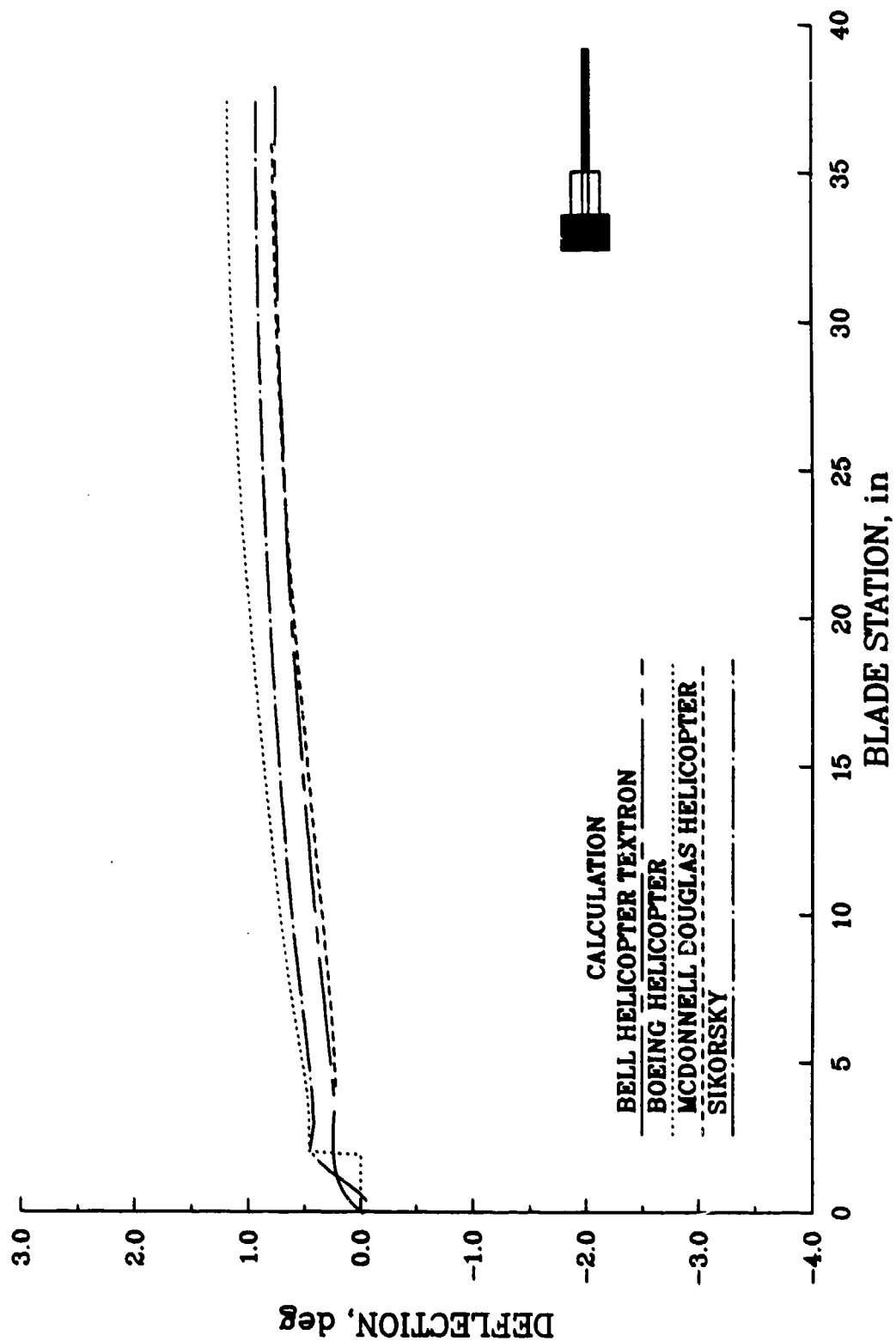
**TORSION EQUILIBRIUM DEFLECTION - TASK 86e**  
**LINEAR AERODYNAMIC COEFFICIENTS**  
**CASE 2 - TORSIONALLY SOFT ROTOR**  
**PITCH ANGLE = -12 deg**



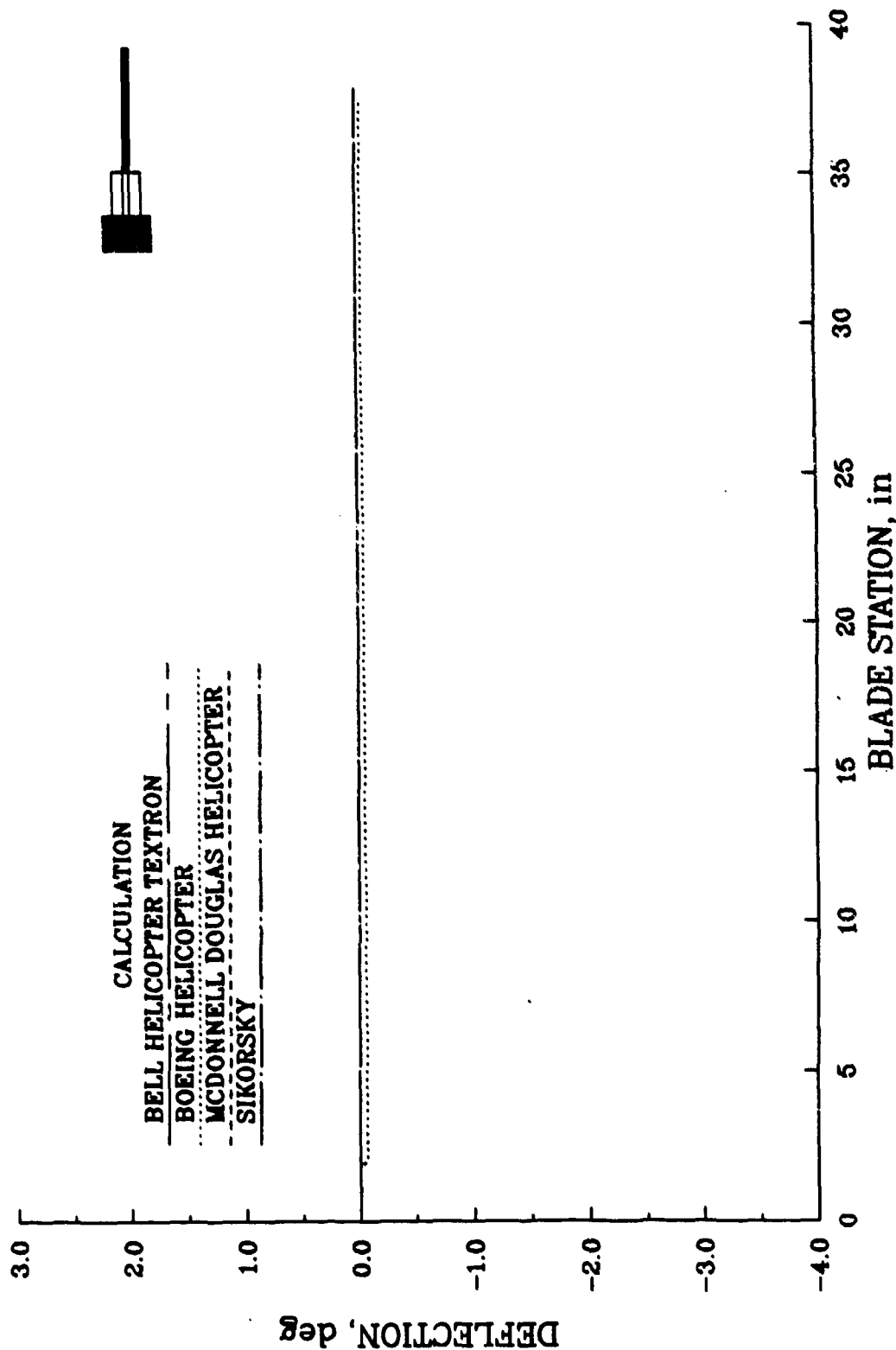
**TORSION EQUILIBRIUM DEFLECTION - TASK 86e**  
**LINEAR AERODYNAMIC COEFFICIENTS**  
**CASE 2 - TORSIONALLY SOFT ROTOR**  
**PITCH ANGLE = -8 deg**



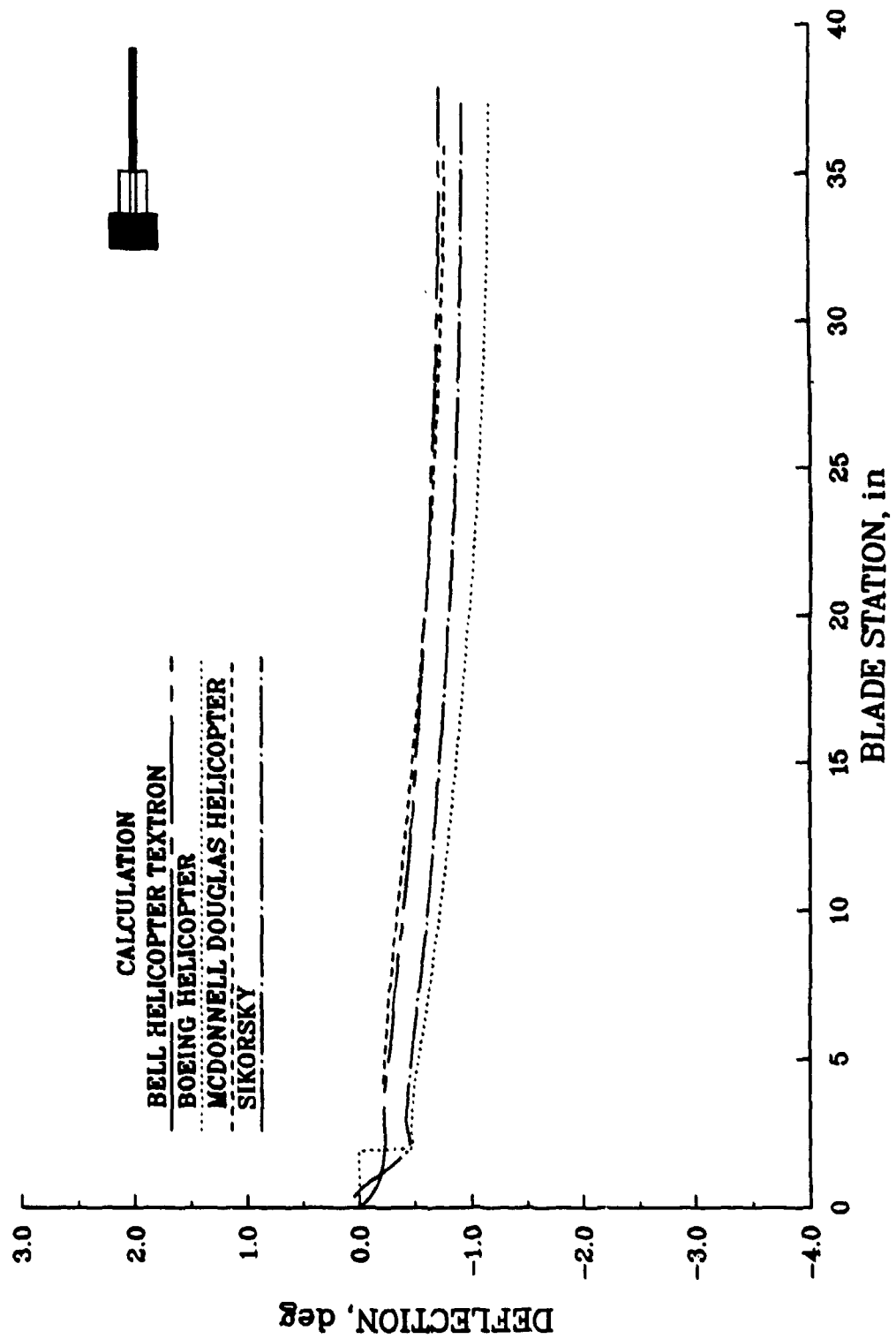
TORSION EQUILIBRIUM DEFLECTION - TASK 86e  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 2 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = -4 deg



TORSION EQUILIBRIUM DEFLECTION - TASK 86e  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 2 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = 0 deg



**TORSION EQUILIBRIUM DEFLECTION - TASK 86e**  
**LINEAR AERODYNAMIC COEFFICIENTS**  
**CASE 2 - TORSIONALLY SOFT ROTOR**  
**PITCH ANGLE = 4 deg**

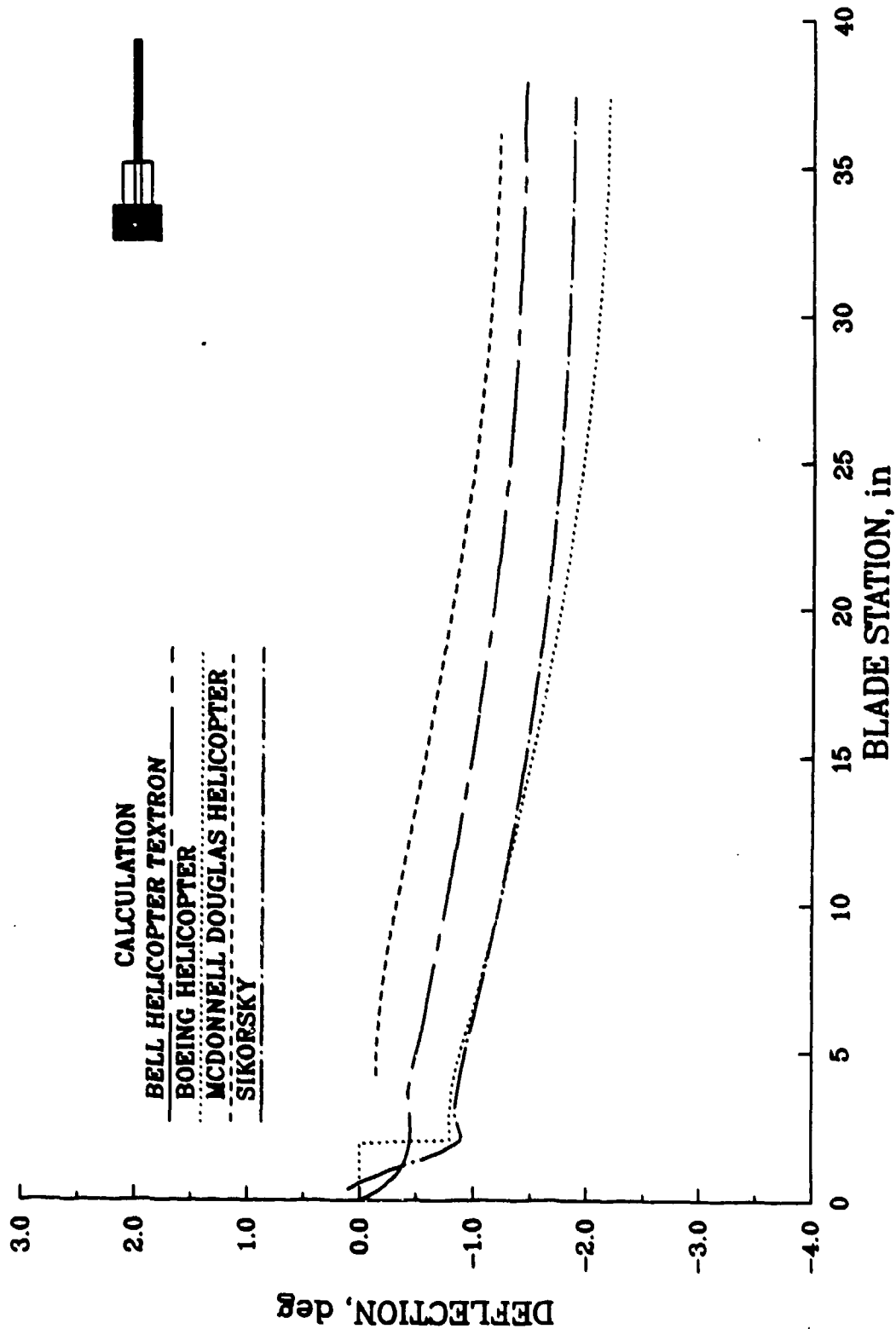


# TORSION EQUILIBRIUM DEFLECTION - TASK 86e

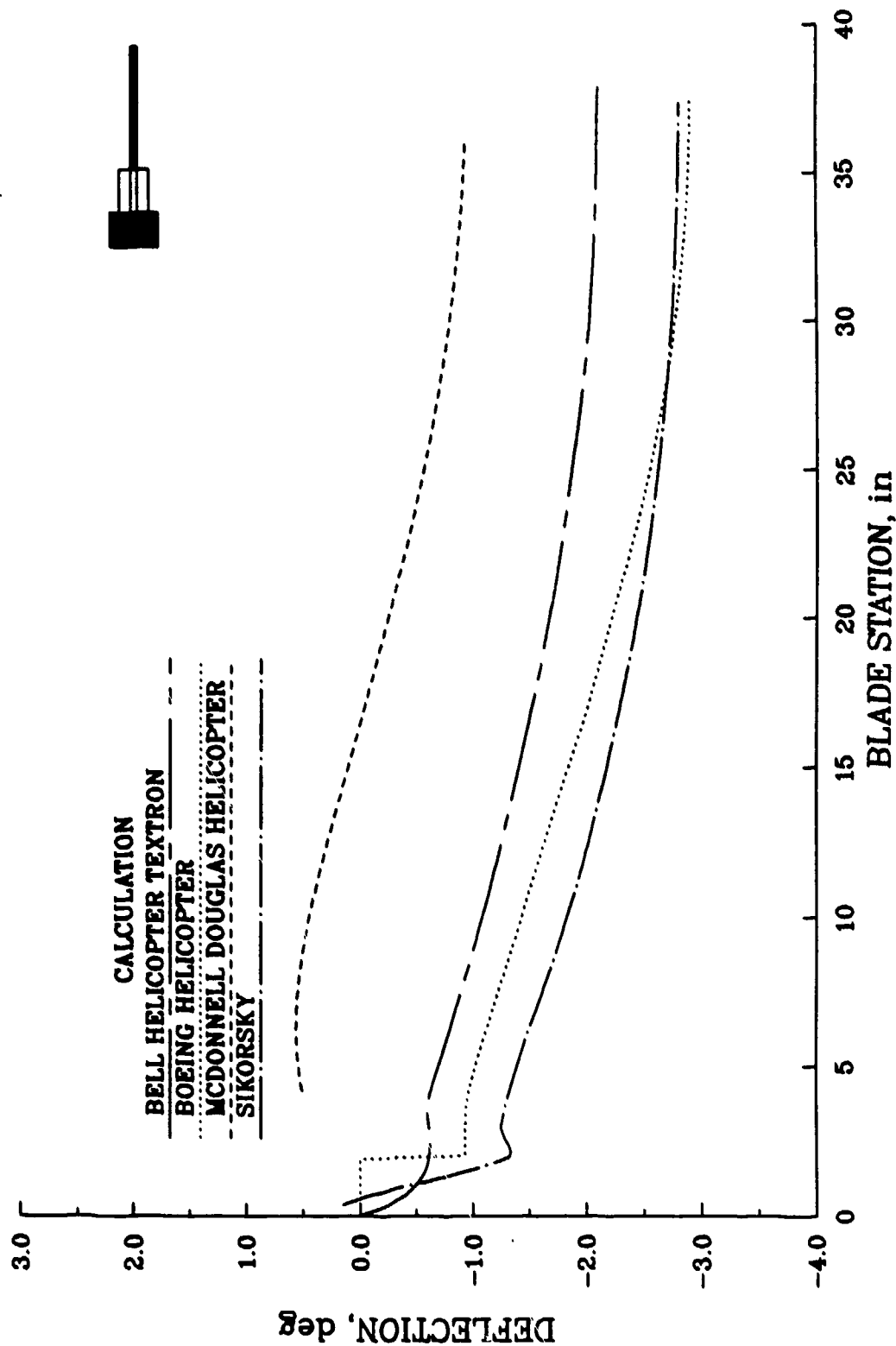
## LINEAR AERODYNAMIC COEFFICIENTS

### CASE 2 - TORSIONALLY SOFT ROTOR

PITCH ANGLE = 8 deg

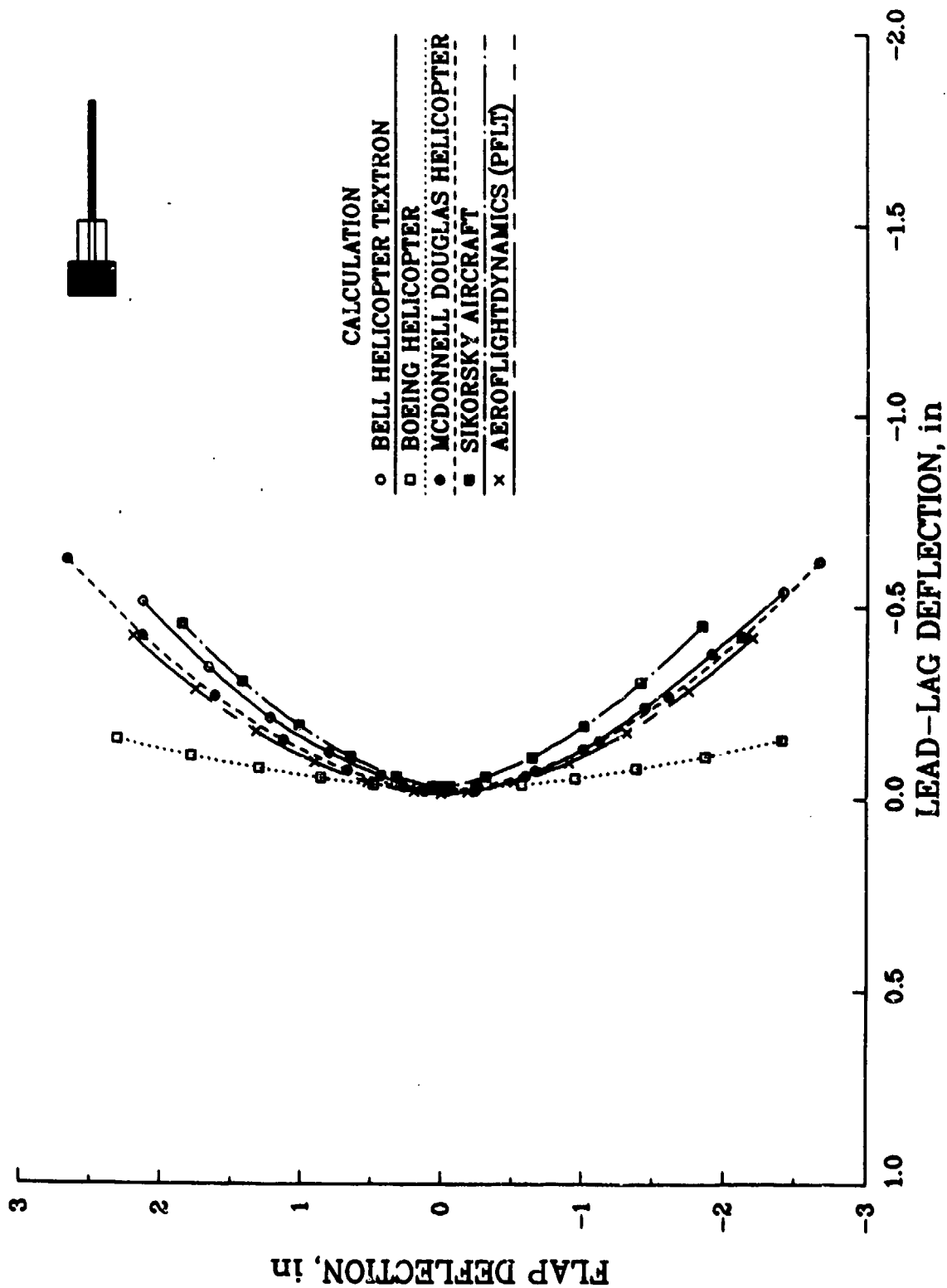


**TORSION EQUILIBRIUM DEFLECTION - TASK 86e**  
**LINEAR AERODYNAMIC COEFFICIENTS**  
**CASE 2 - TORSIONALLY SOFT ROTOR**  
**PITCH ANGLE = 12 deg**

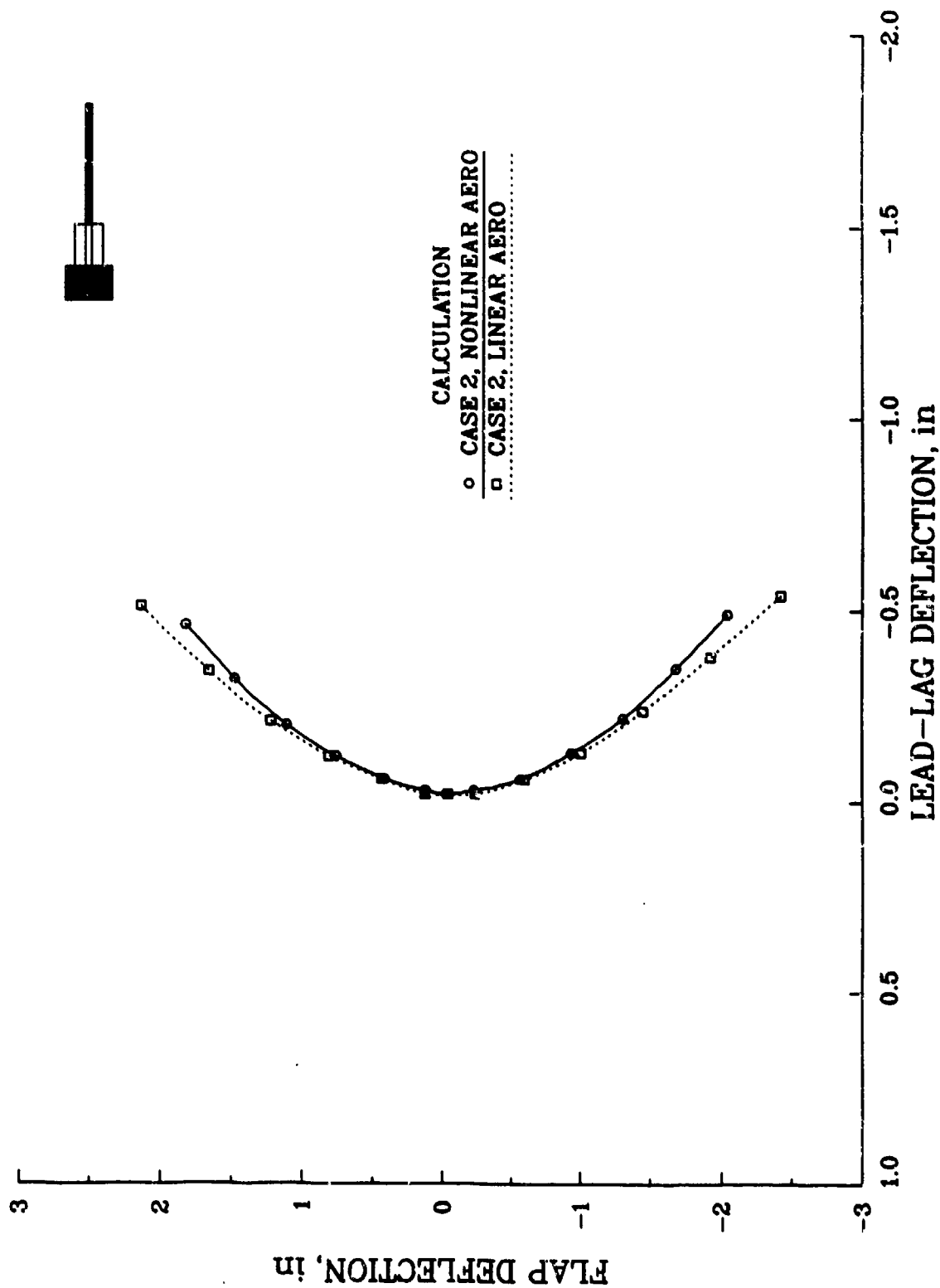




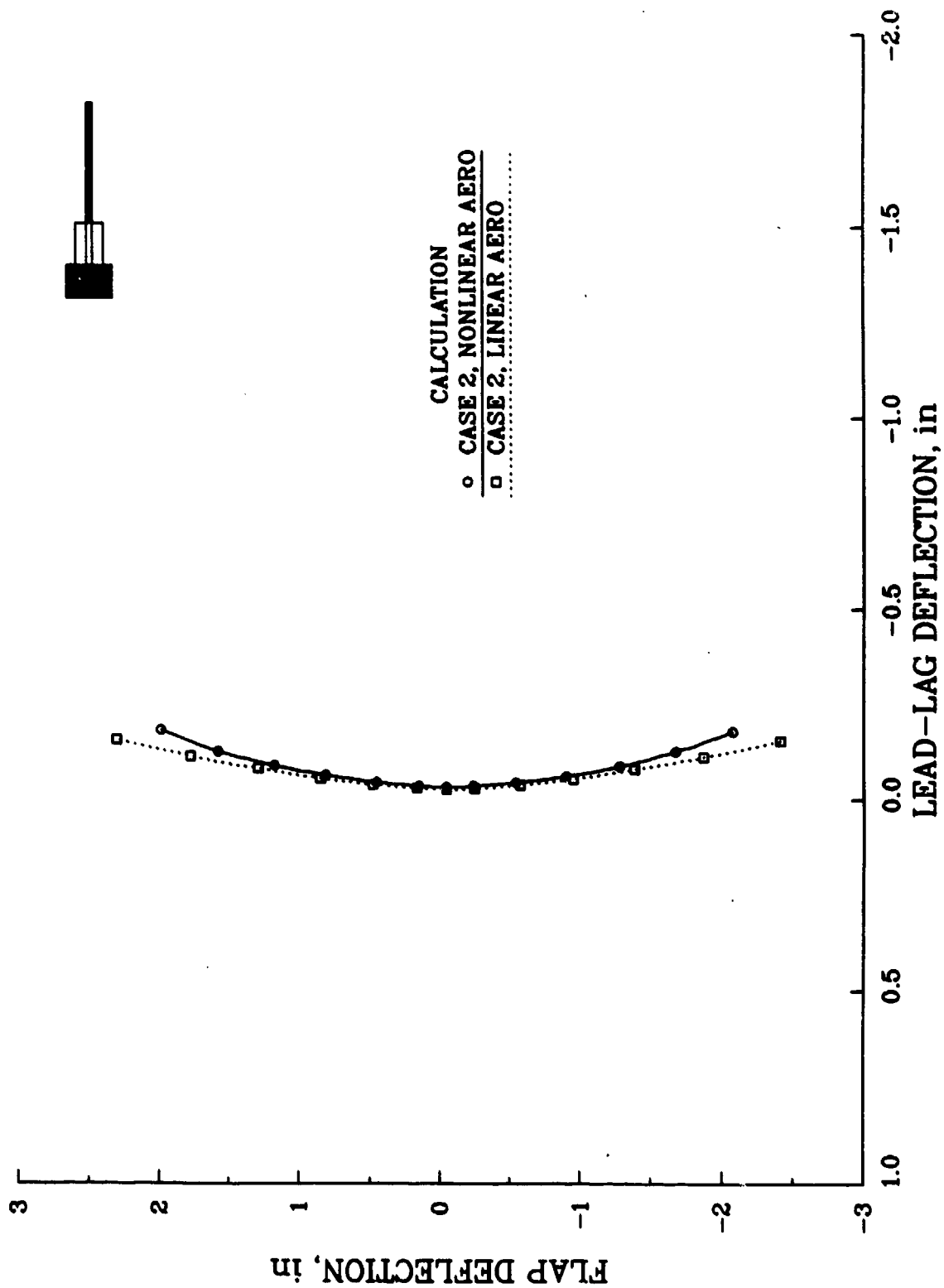
BLADE TIP DEFLECTION - TASK 86e  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 2 - TORSIONALLY SOFT ROTOR



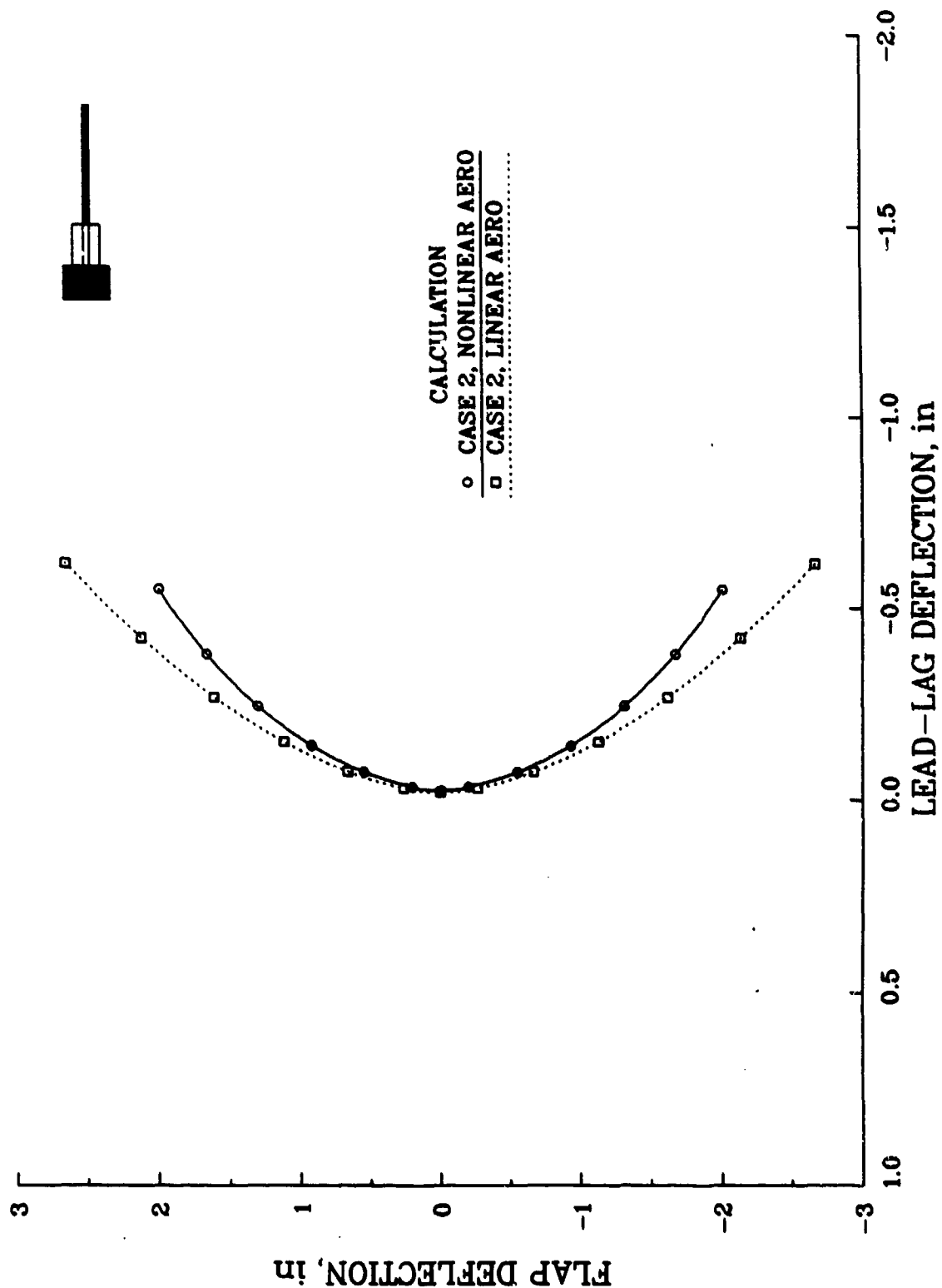
# BLADE TIP DEFLECTION TORSIONALLY SOFT ROTOR BELL HELICOPTER TEXTRON



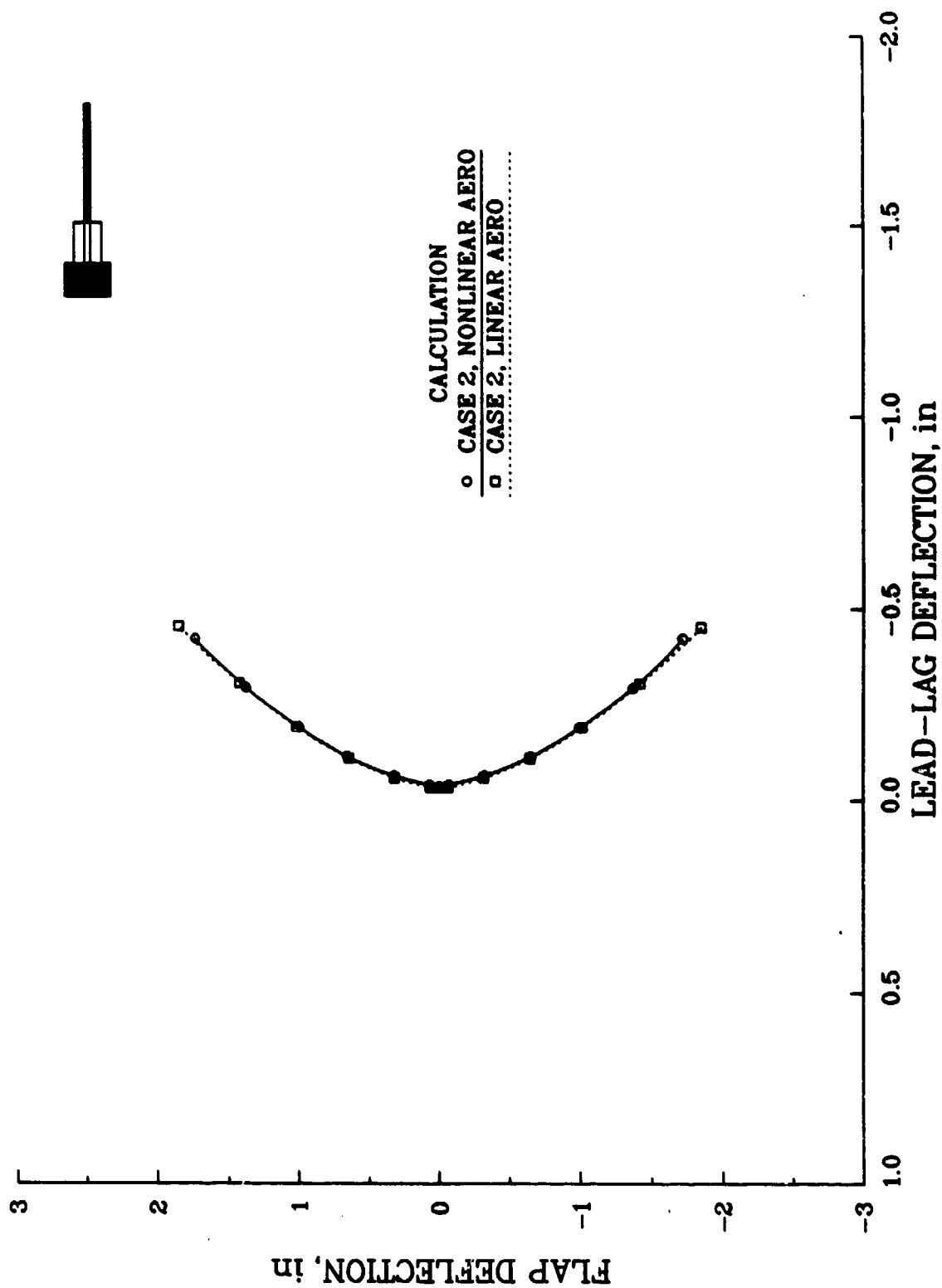
# BLADE TIP DEFLECTION TORSIONALLY SOFT ROTOR BOEING HELICOPTER



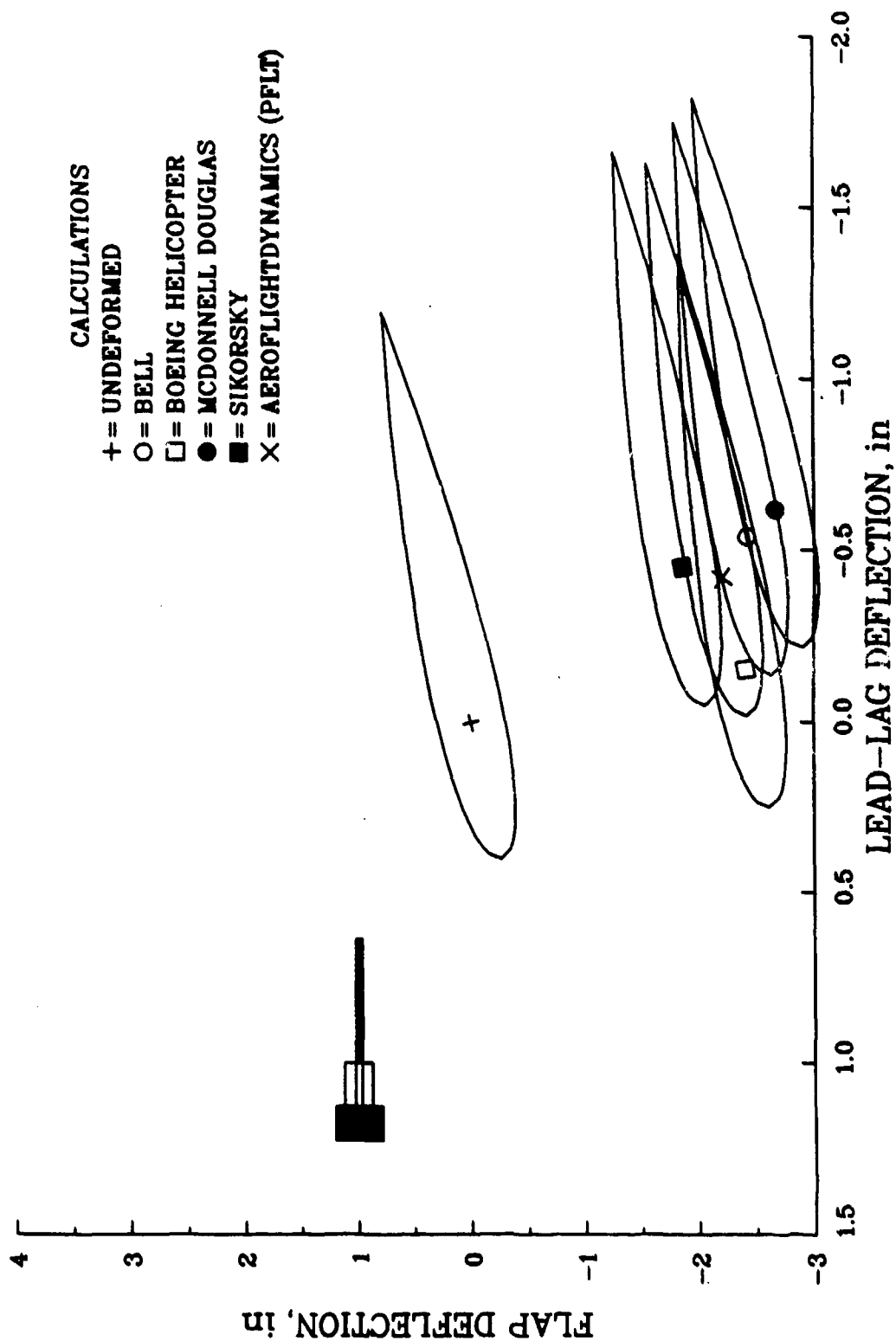
BLADE TIP DEFLECTION  
TORSIONALLY SOFT ROTOR  
MCDONNELL DOUGLAS HELICOPTER



# BLADE TIP DEFLECTION TORSIONALLY SOFT ROTOR SIKORSKY AIRCRAFT

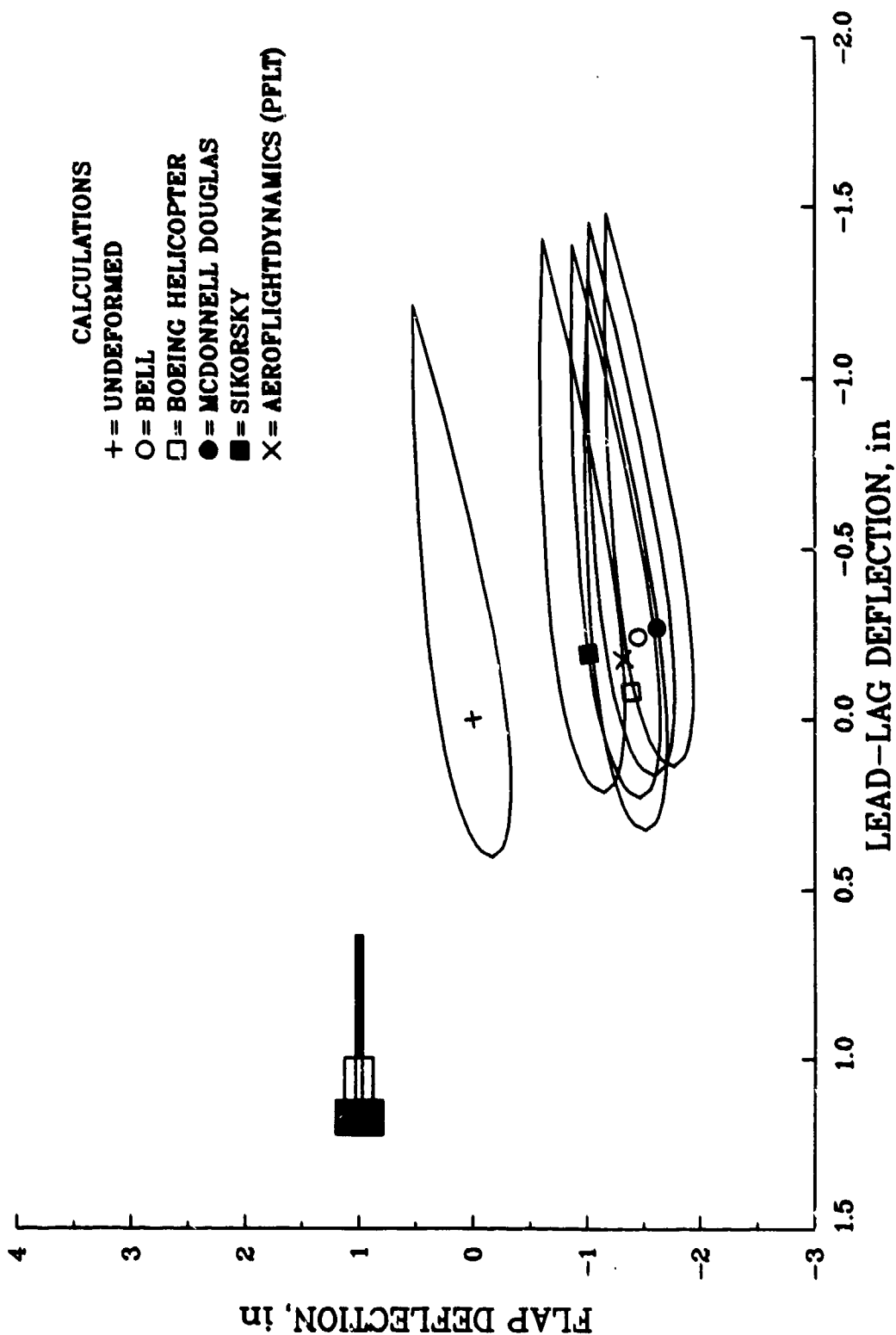


BLADE TIP DEFLECTION - TASK 86e  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 2 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = -12 deg

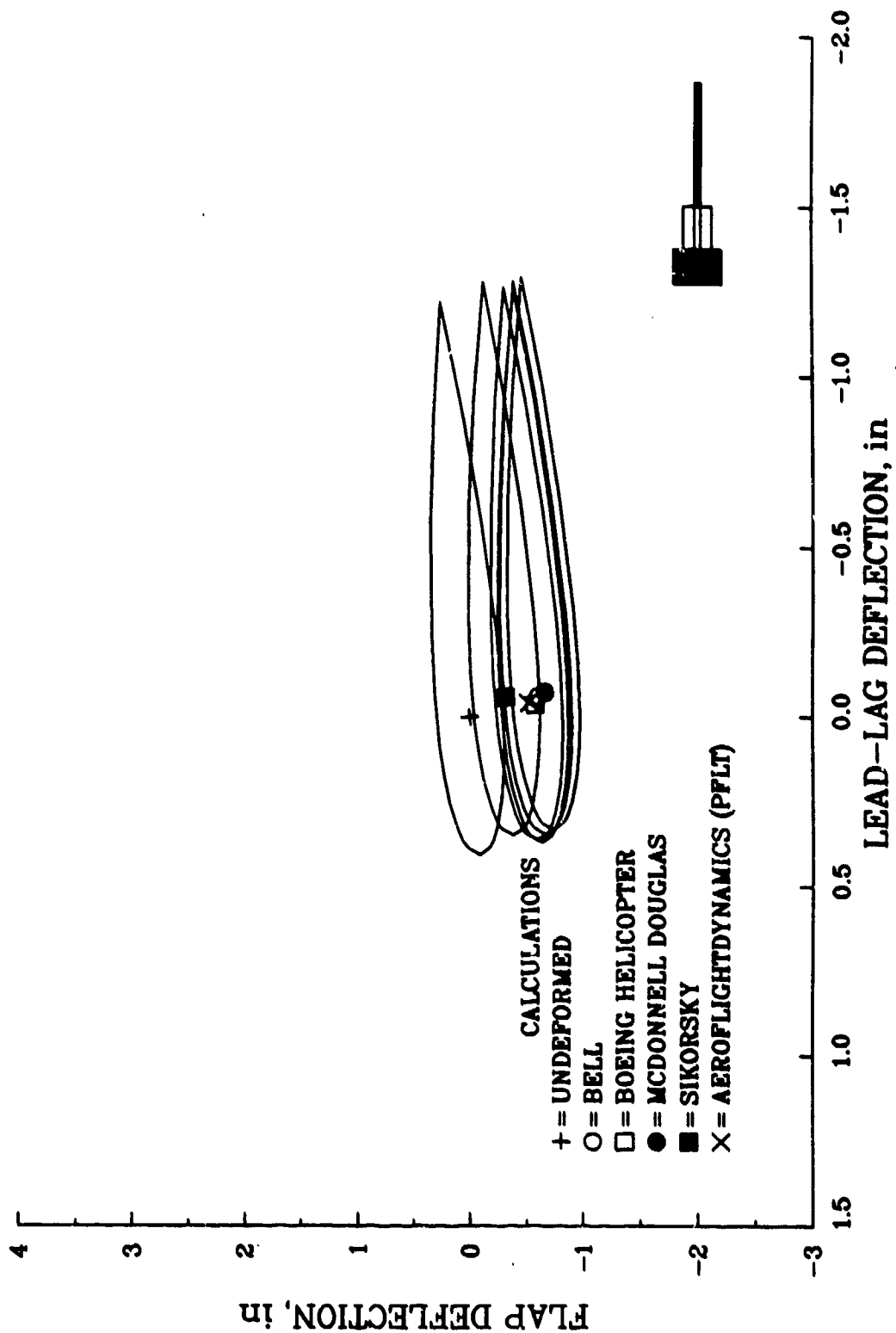


BLADE TIP DEFLECTION - TASK 86e  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 2 - TORSIONALLY SOFT ROTOR

PITCH ANGLE = -8 deg



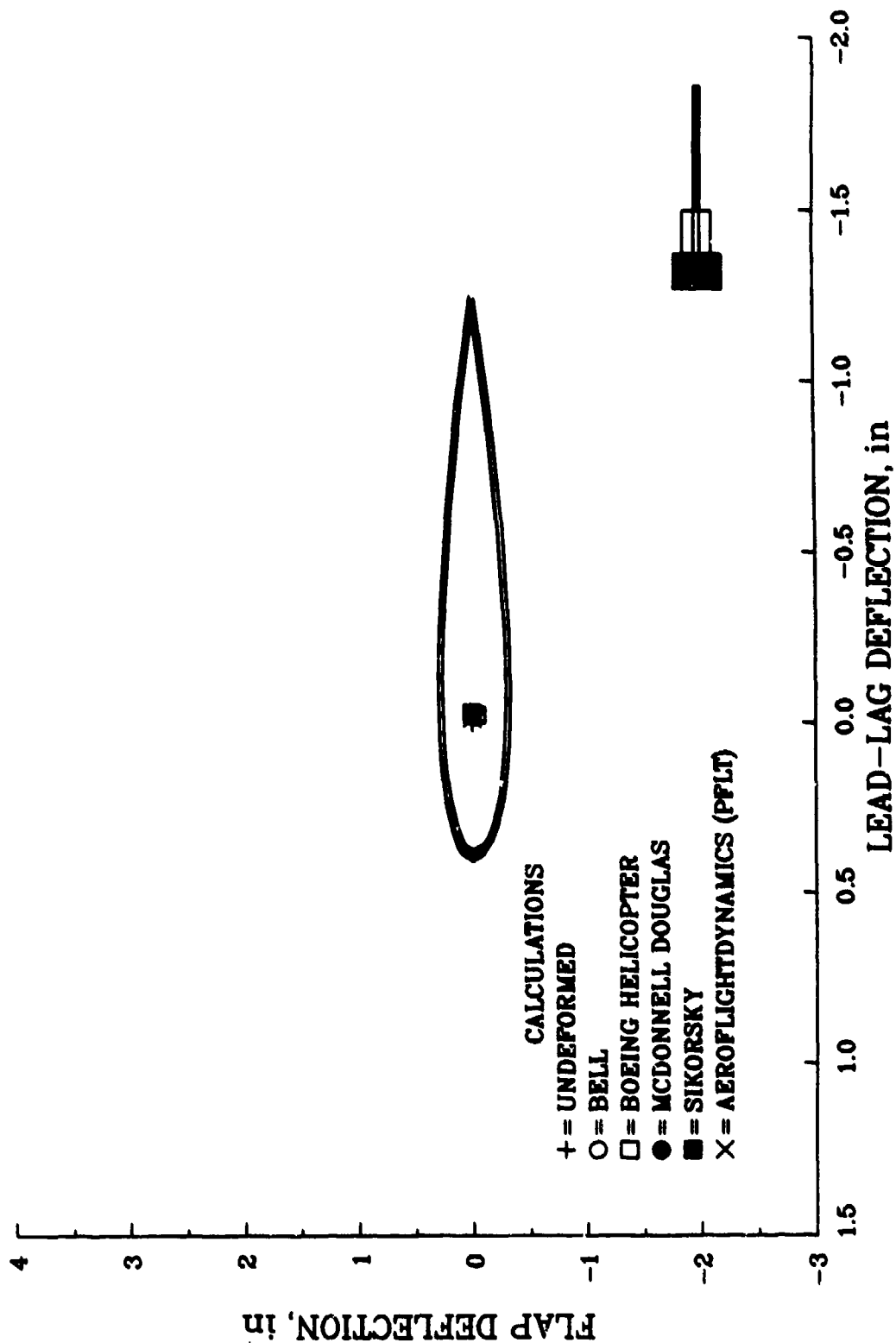
BLADE TIP DEFLECTION - TASK 86e  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 2 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = -4 deg



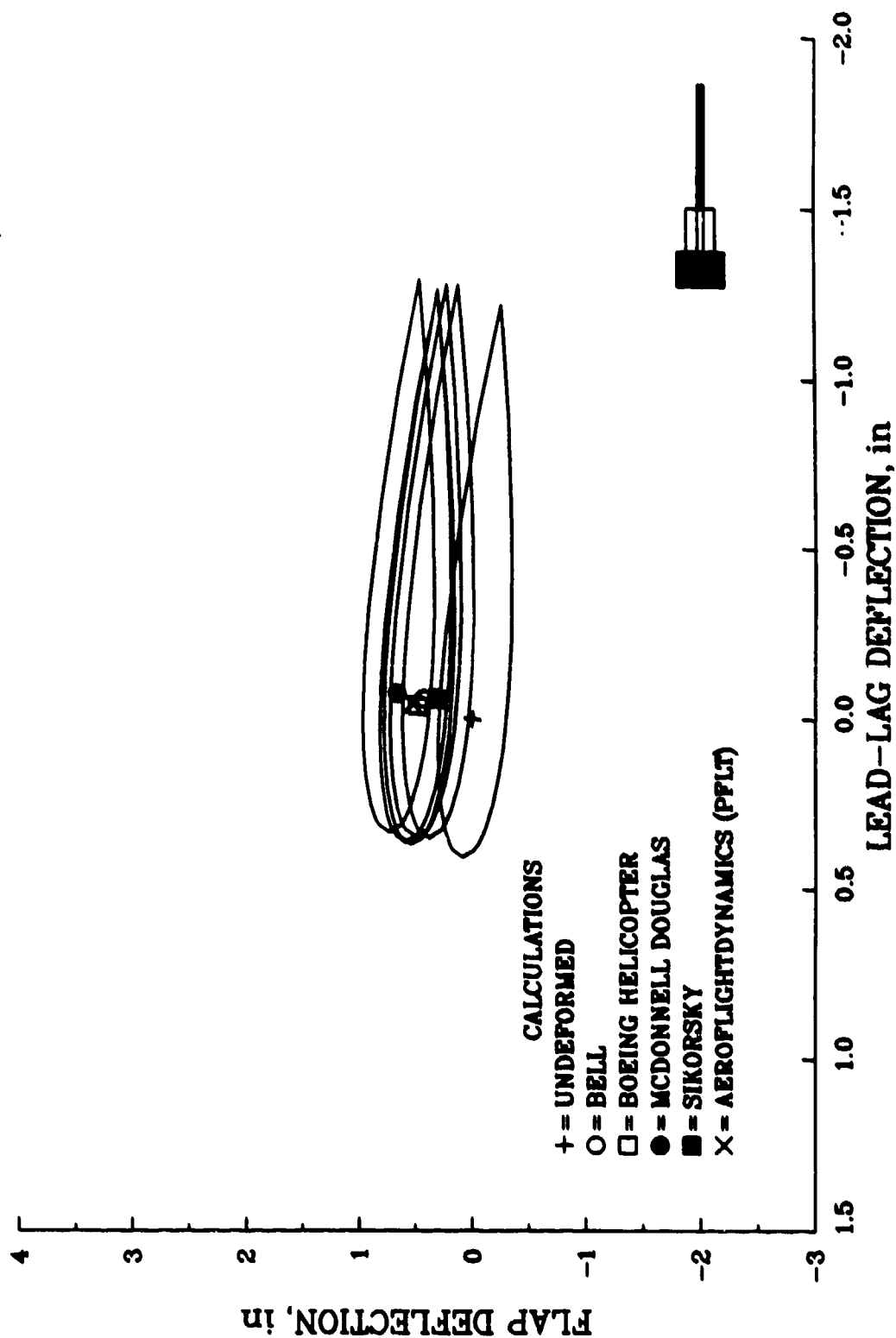


BLADE TIP DEFLECTION - TASK 86e  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 2 - TORSIONALLY SOFT ROTOR

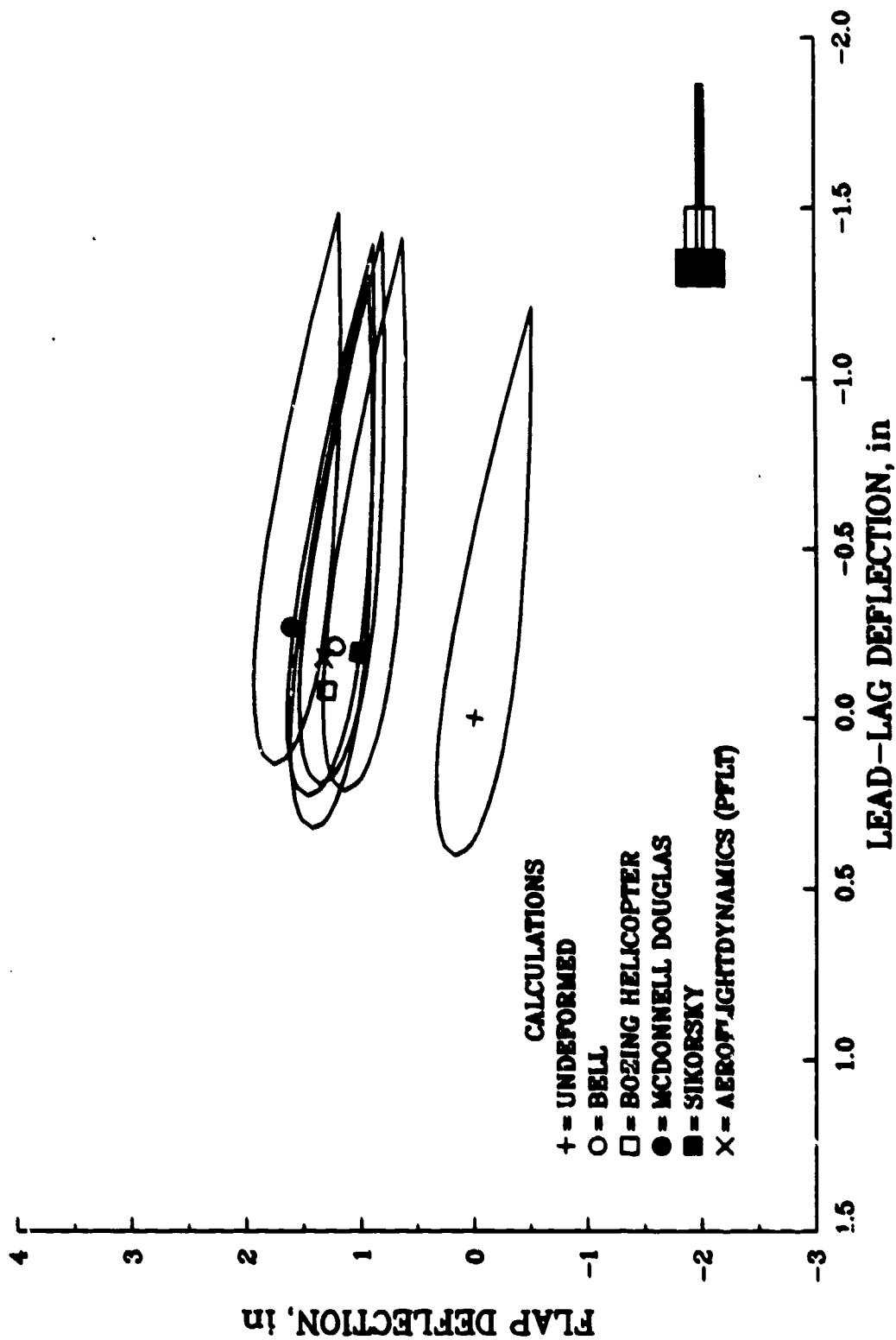
PITCH ANGLE = 0 deg



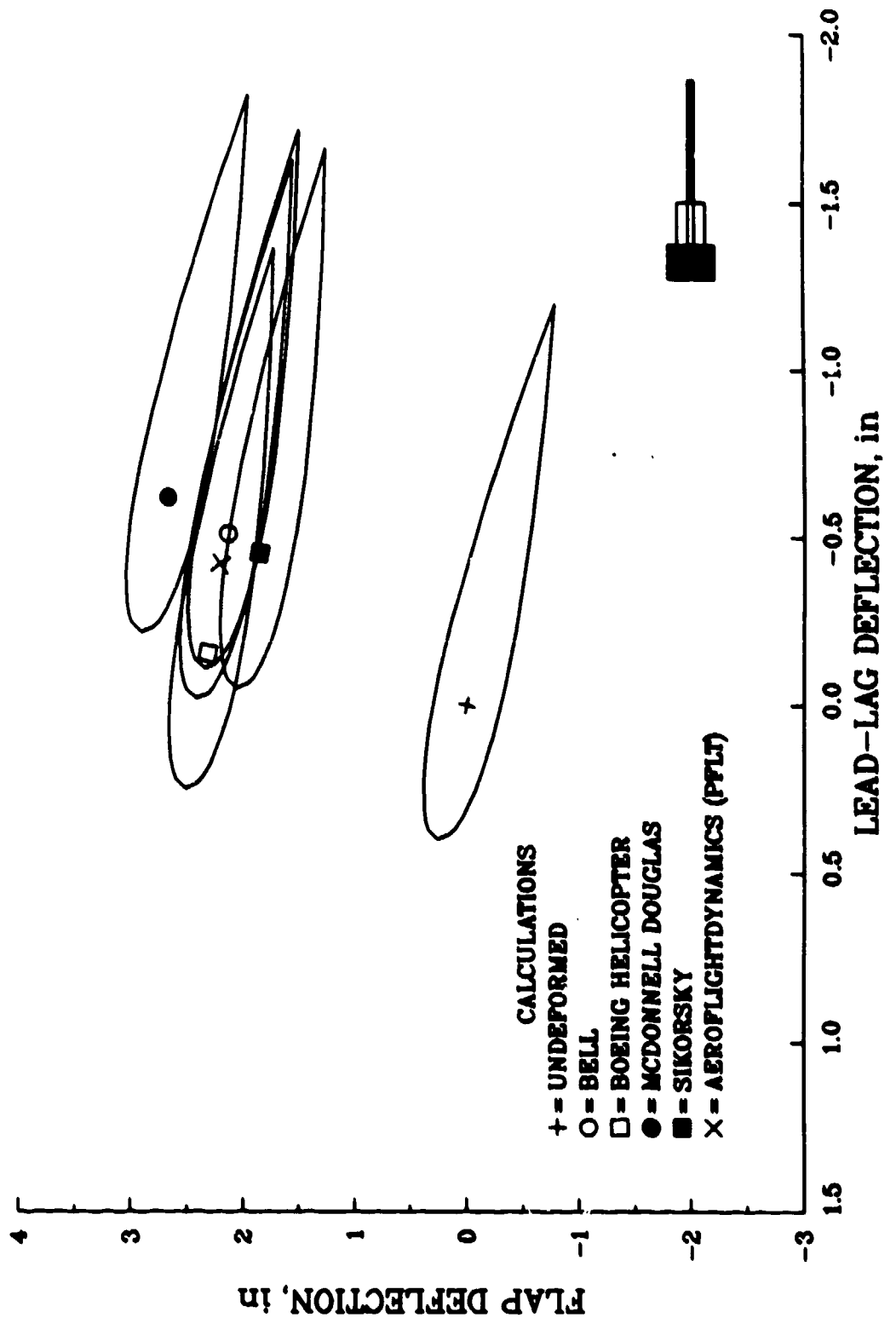
BLADE TIP DEFLECTION - TASK 86e  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 2 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = 4 deg



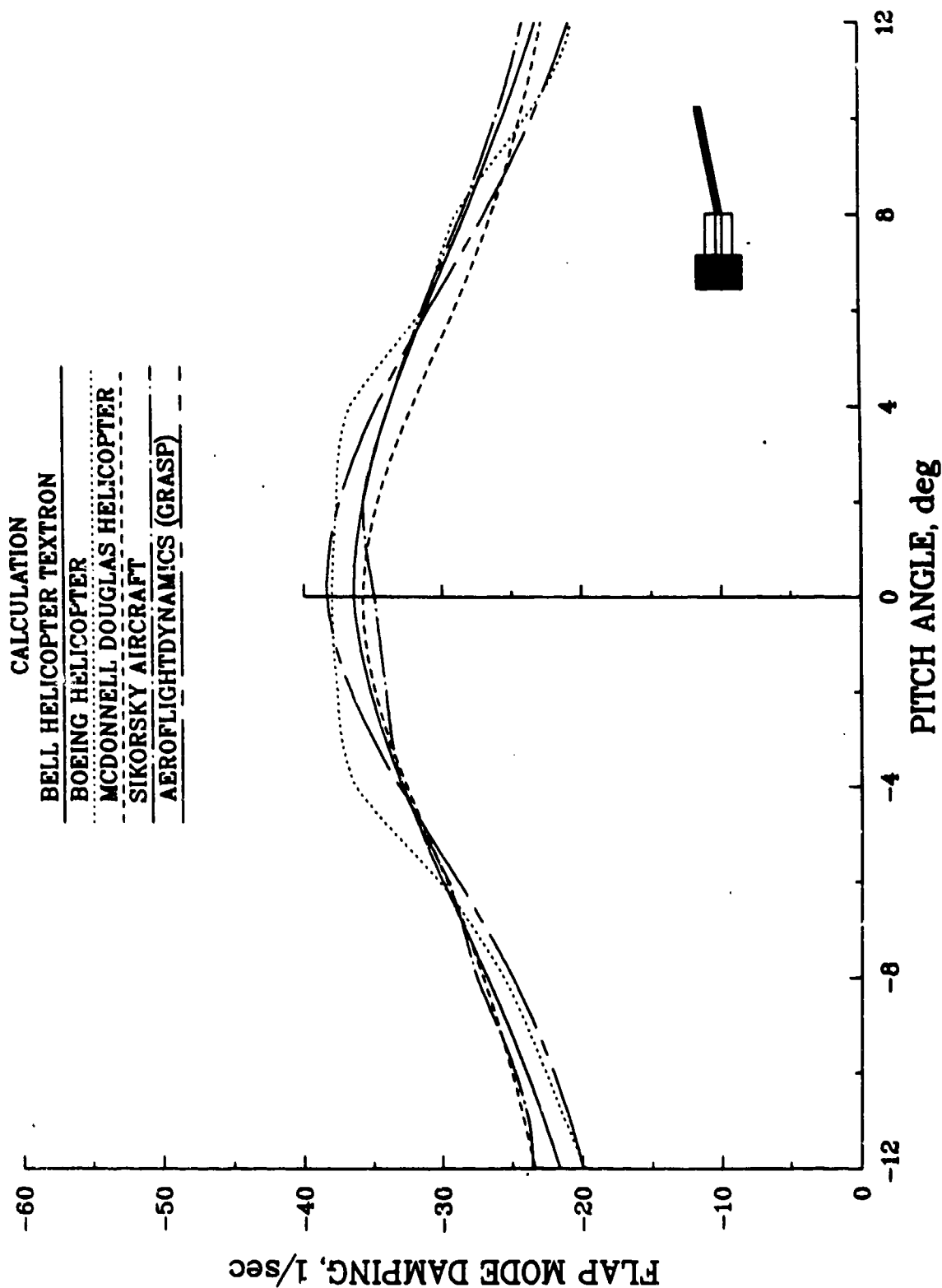
BLADE TIP DEFLECTION - TASK 86e  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 2 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = 8 deg



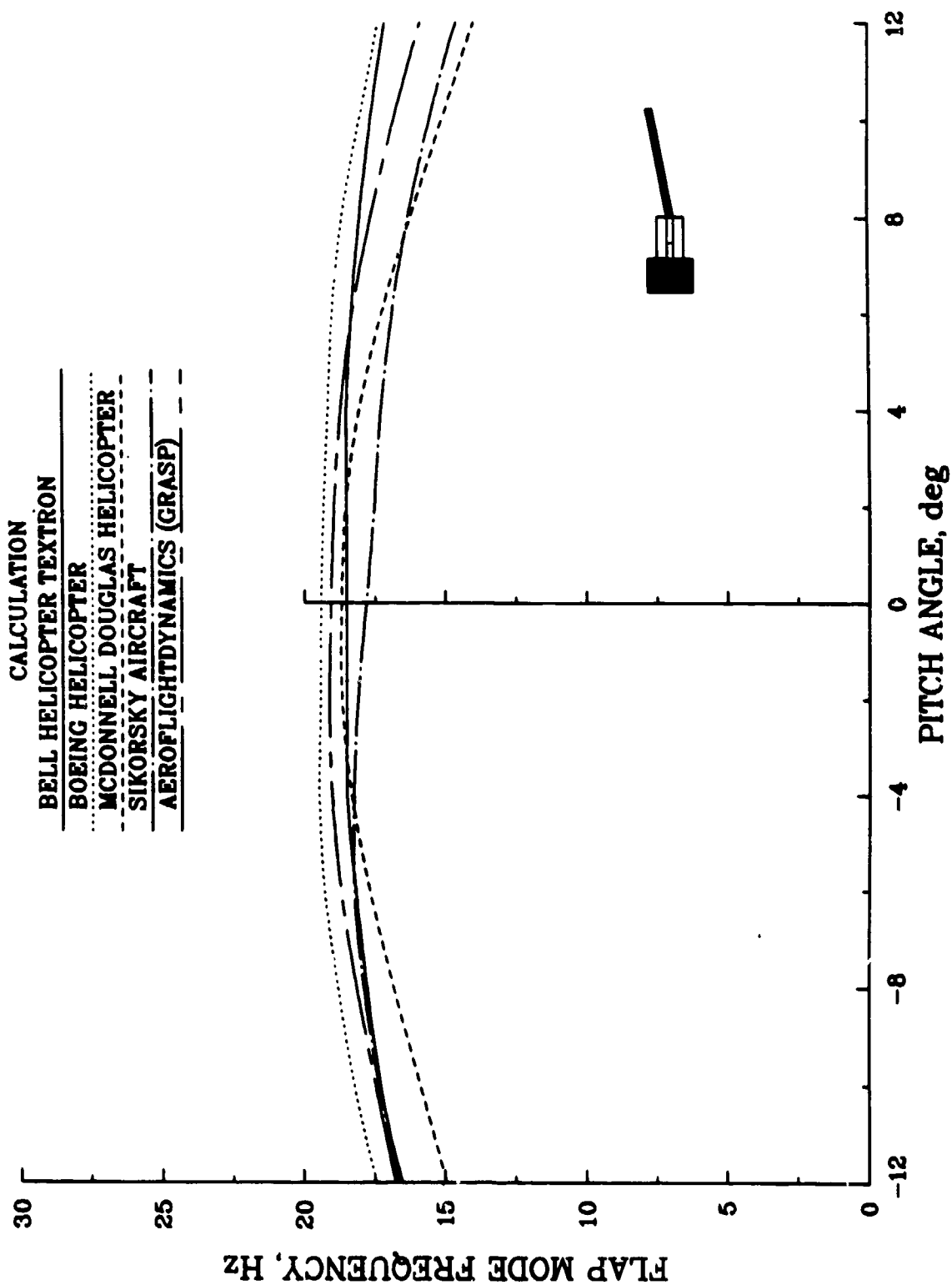
BLADE TIP DEFLECTION - TASK 86e  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 2 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = 12 deg



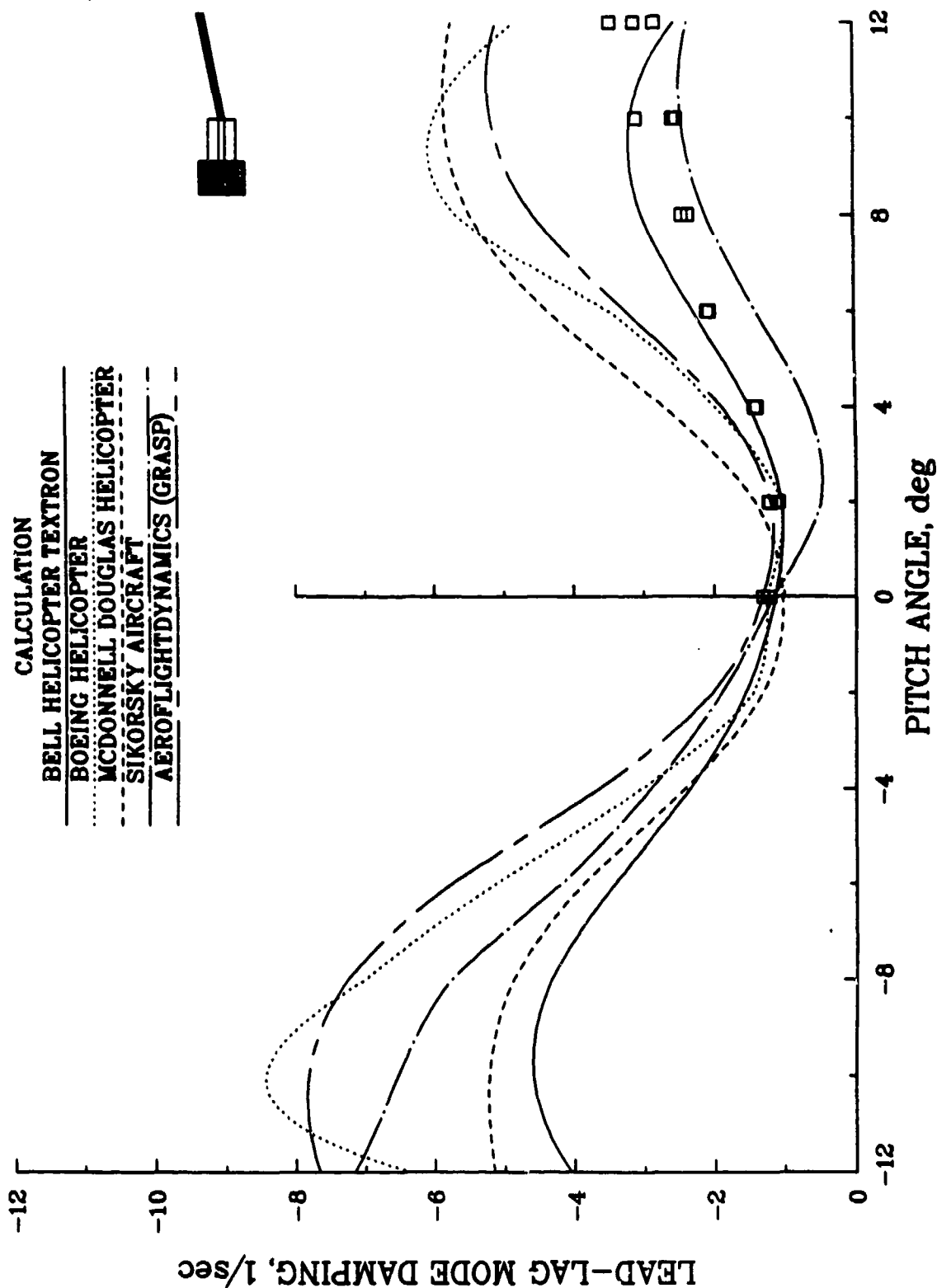
FLAP MODE DAMPING - TASK 86f  
 NONLINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR



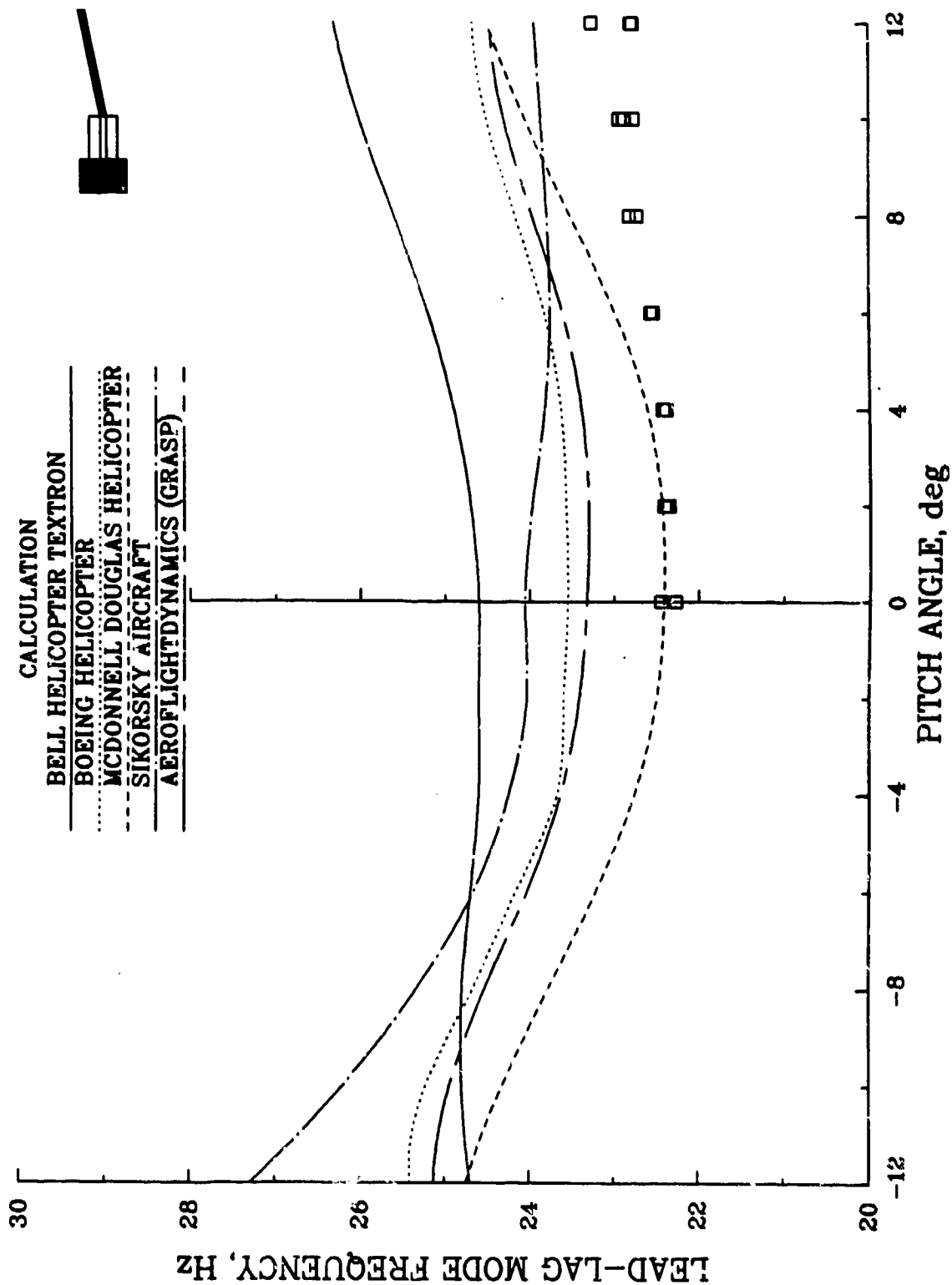
FLAP MODE FREQUENCY - TASK 86f  
 NONLINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR



# LEAD-LAG MODE DAMPING - TASK 86f NONLINEAR AERODYNAMIC COEFFICIENTS CASE 6 - TORSIONALLY SOFT ROTOR

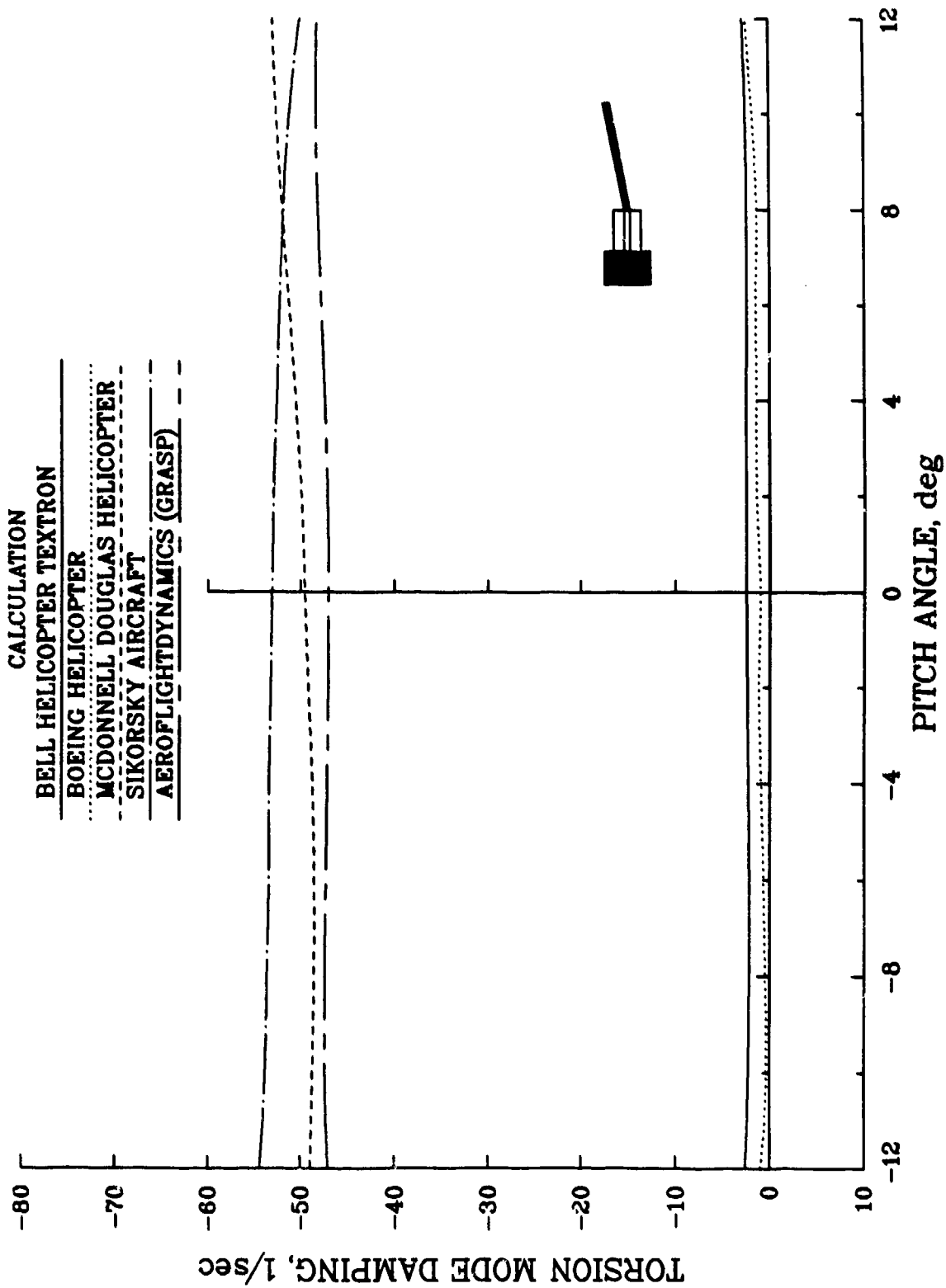


# LEAD-LAG MODE FREQUENCY - TASK 86f NONLINEAR AERODYNAMIC COEFFICIENTS CASE 6 - TORSIONALLY SOFT ROTOR

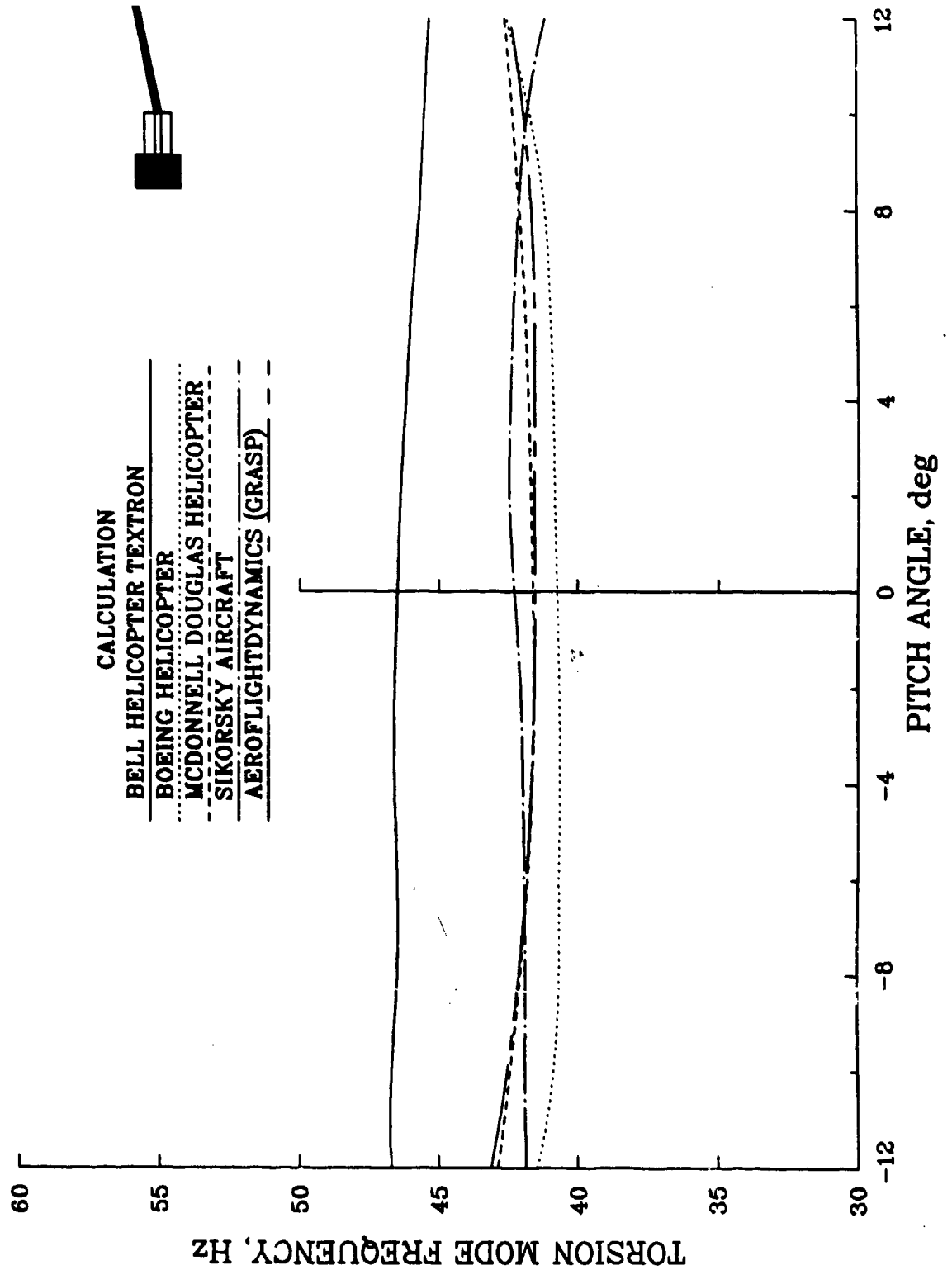




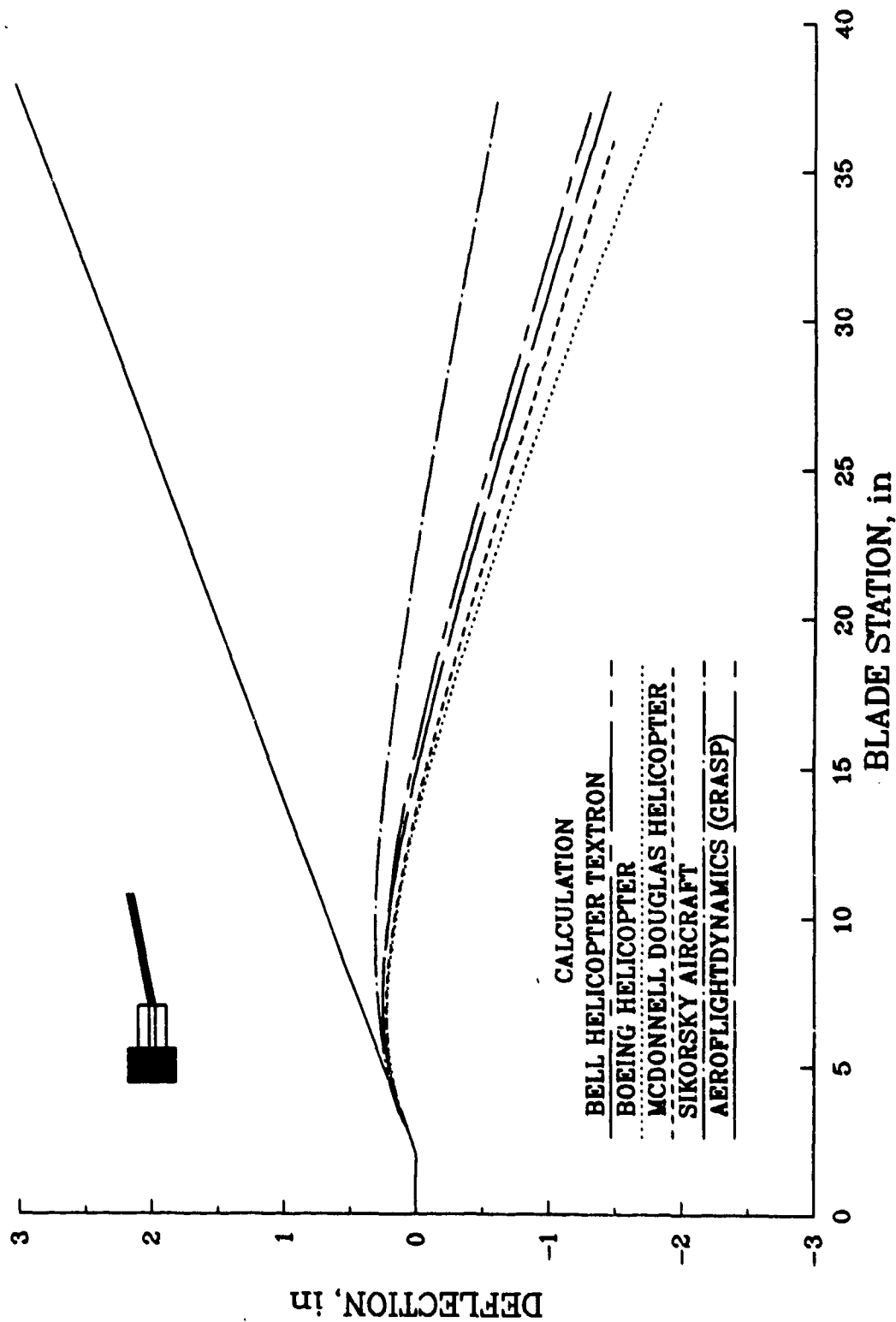
TORSION MODE DAMPING - TASK 86f  
NONLINEAR AERODYNAMIC COEFFICIENTS  
CASE 6 - TORSIONALLY SOFT ROTOR



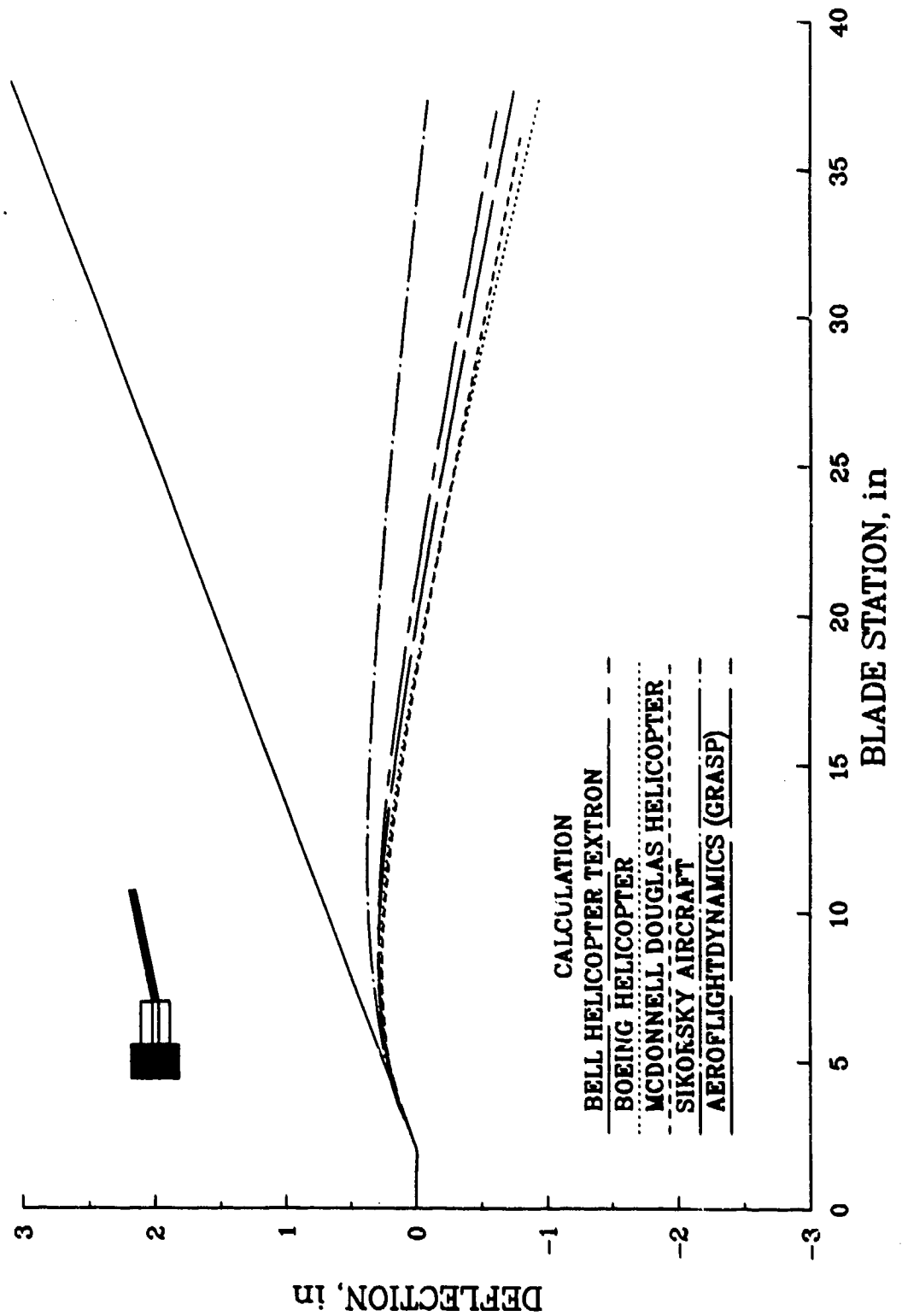
TORSION MODE FREQUENCY - TASK 86f  
 NONLINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR



FLAP EQUILIBRIUM DEFLECTION - TASK 86f  
 NONLINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = -12 deg

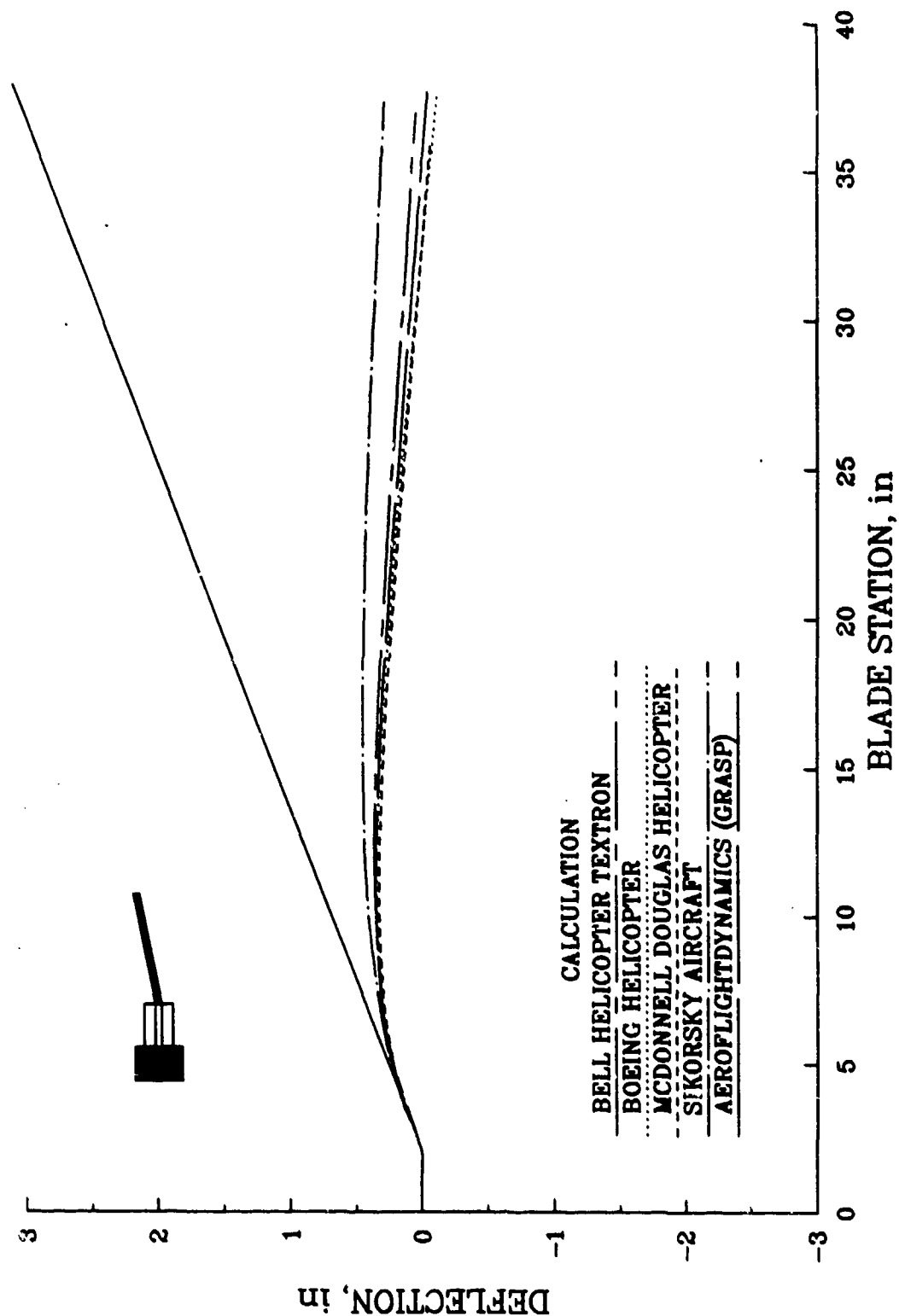


FLAP EQUILIBRIUM DEFLECTION - TASK 86f  
 NONLINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = -8 deg



FLAP EQUILIBRIUM DEFLECTION - TASK 86f  
 NONLINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR

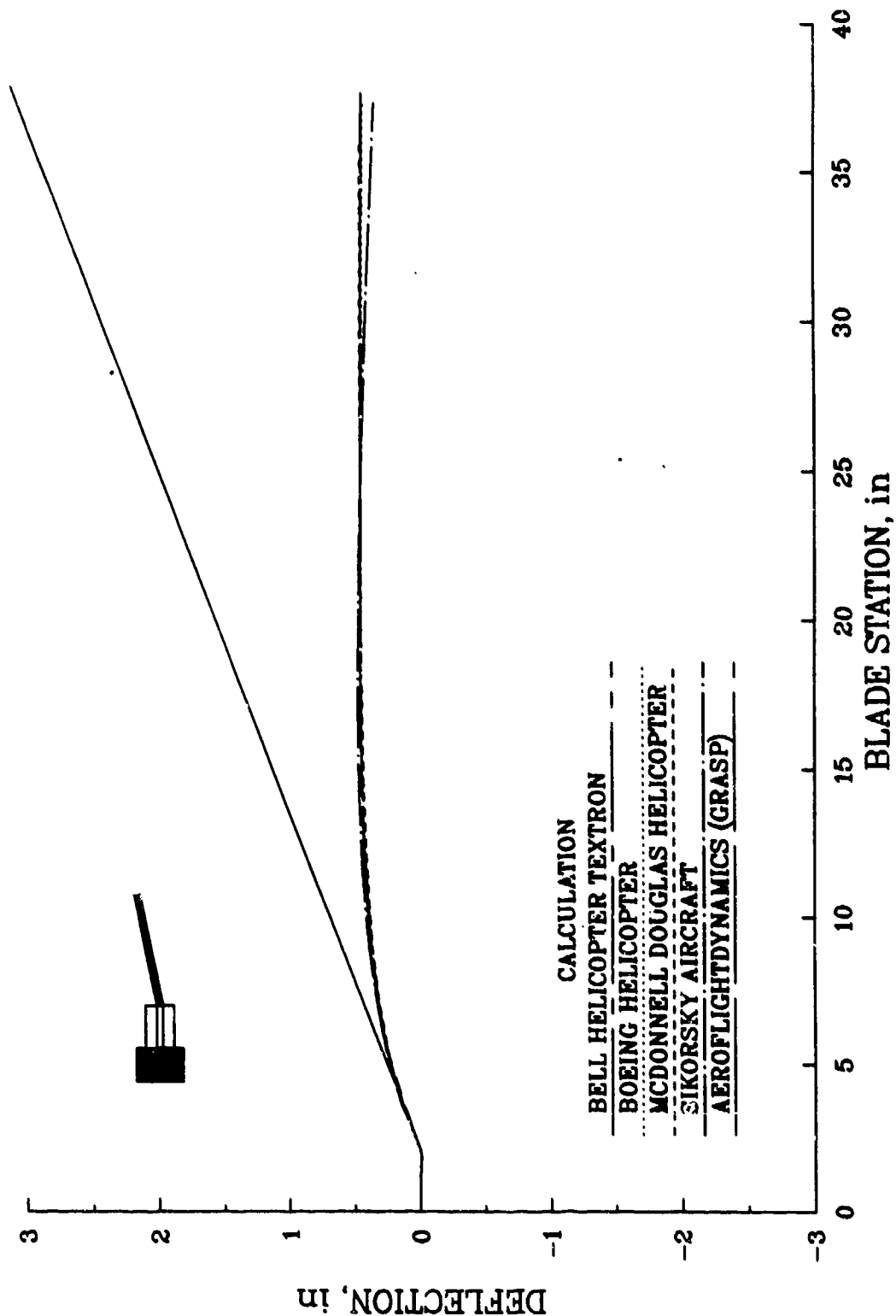
PITCH ANGLE = -4 deg



FLAP EQUILIBRIUM DEFLECTION - TASK 86f  
NONLINEAR AERODYNAMIC COEFFICIENTS

CASE 6 - TORSIONALLY SOFT ROTOR

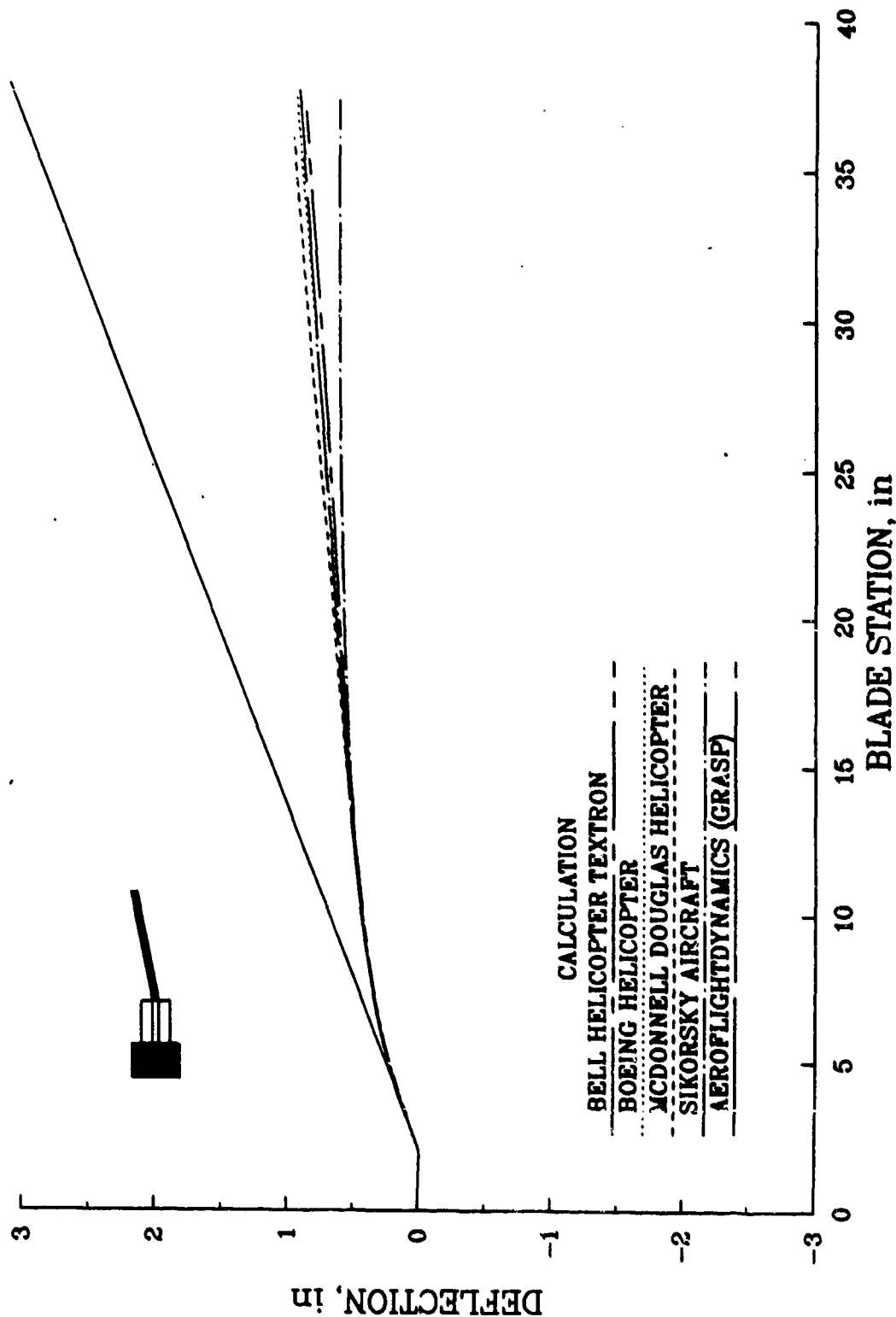
PITCH ANGLE = 0 deg



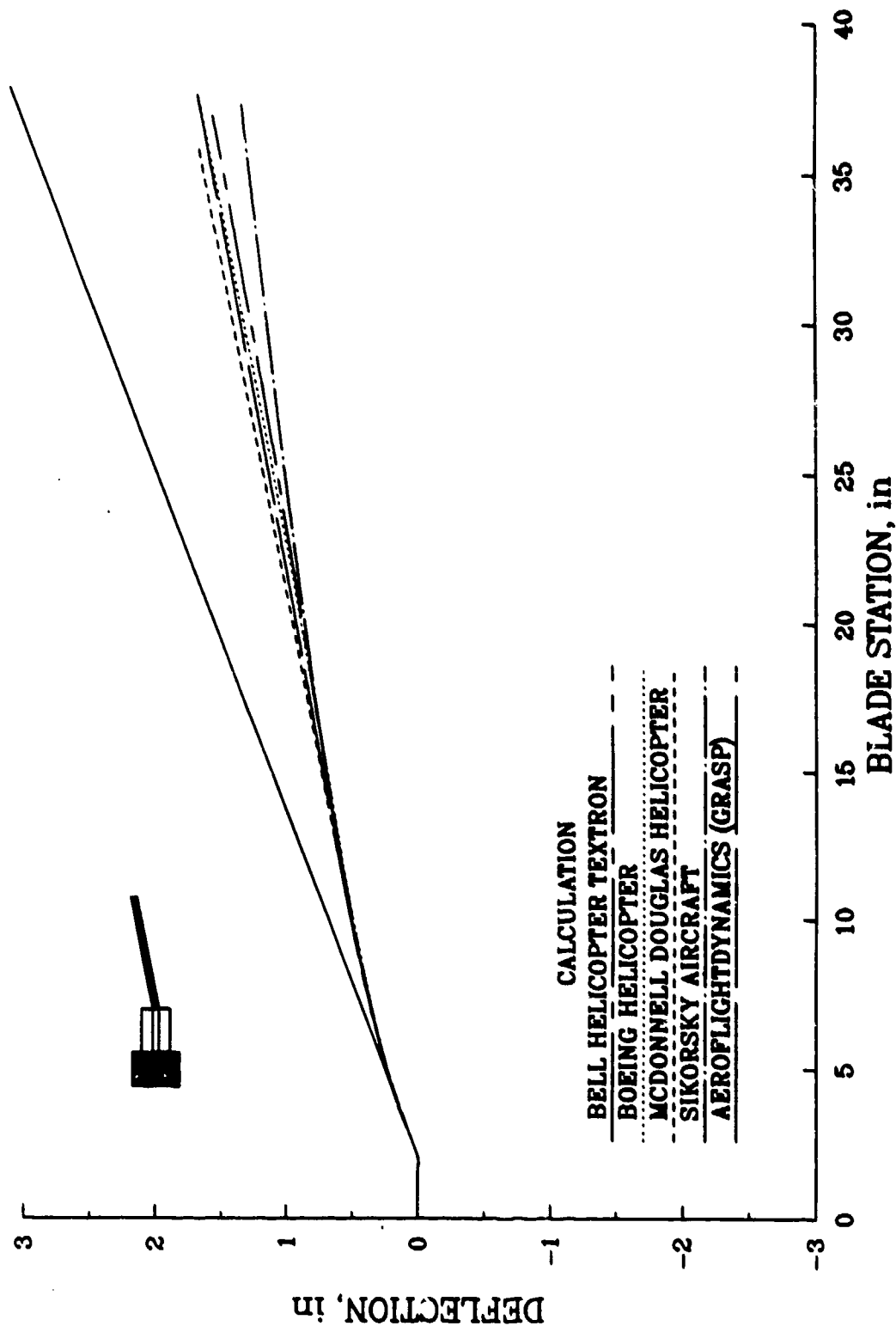
FLAP EQUILIBRIUM DEFLECTION - TASK 86f  
NONLINEAR AERODYNAMIC COEFFICIENTS

CASE 6 - TORSIONALLY SOFT ROTOR

PITCH ANGLE = 4 deg

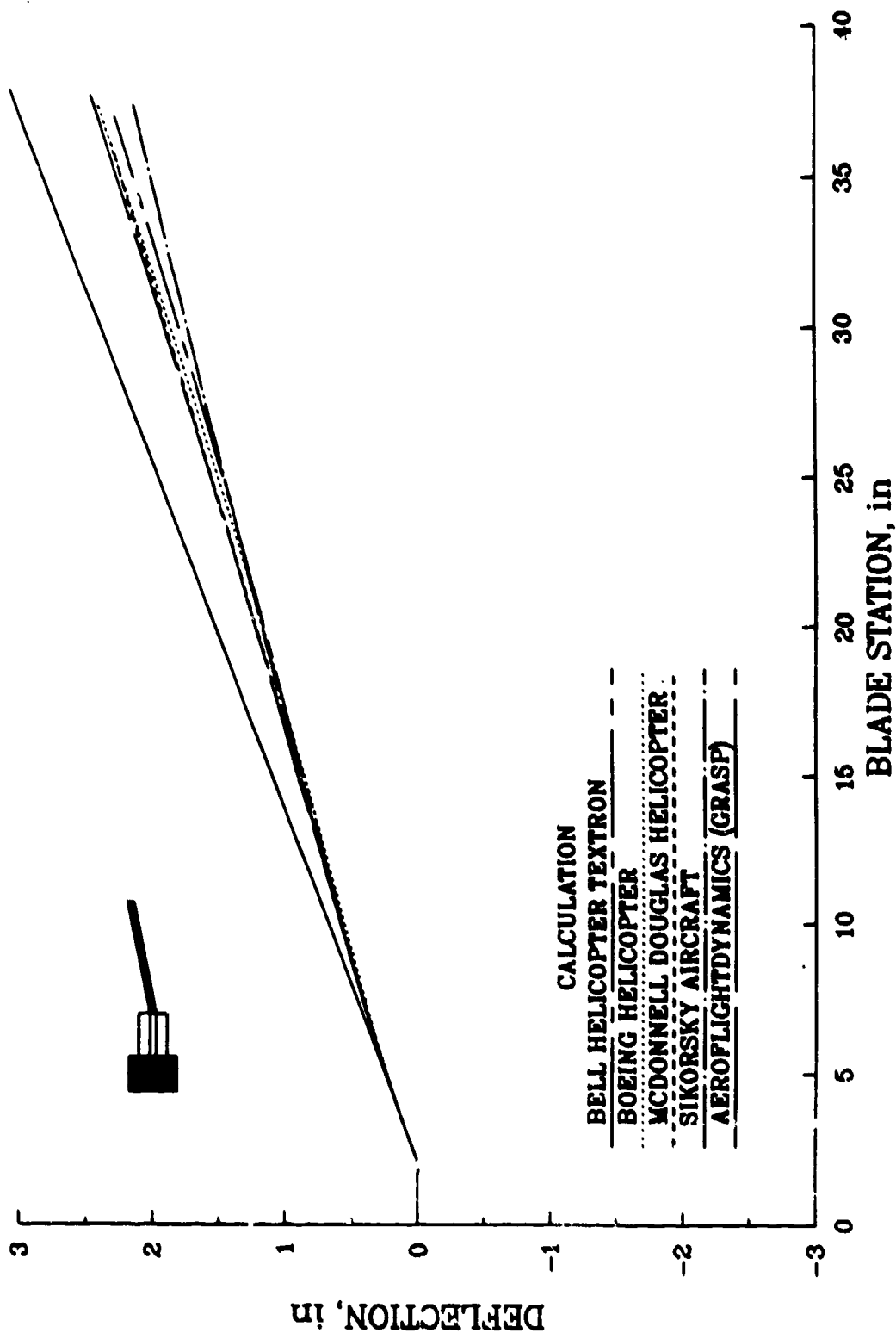


FLAP EQUILIBRIUM DEFLECTION - TASK 86f  
 NONLINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = 8 deg

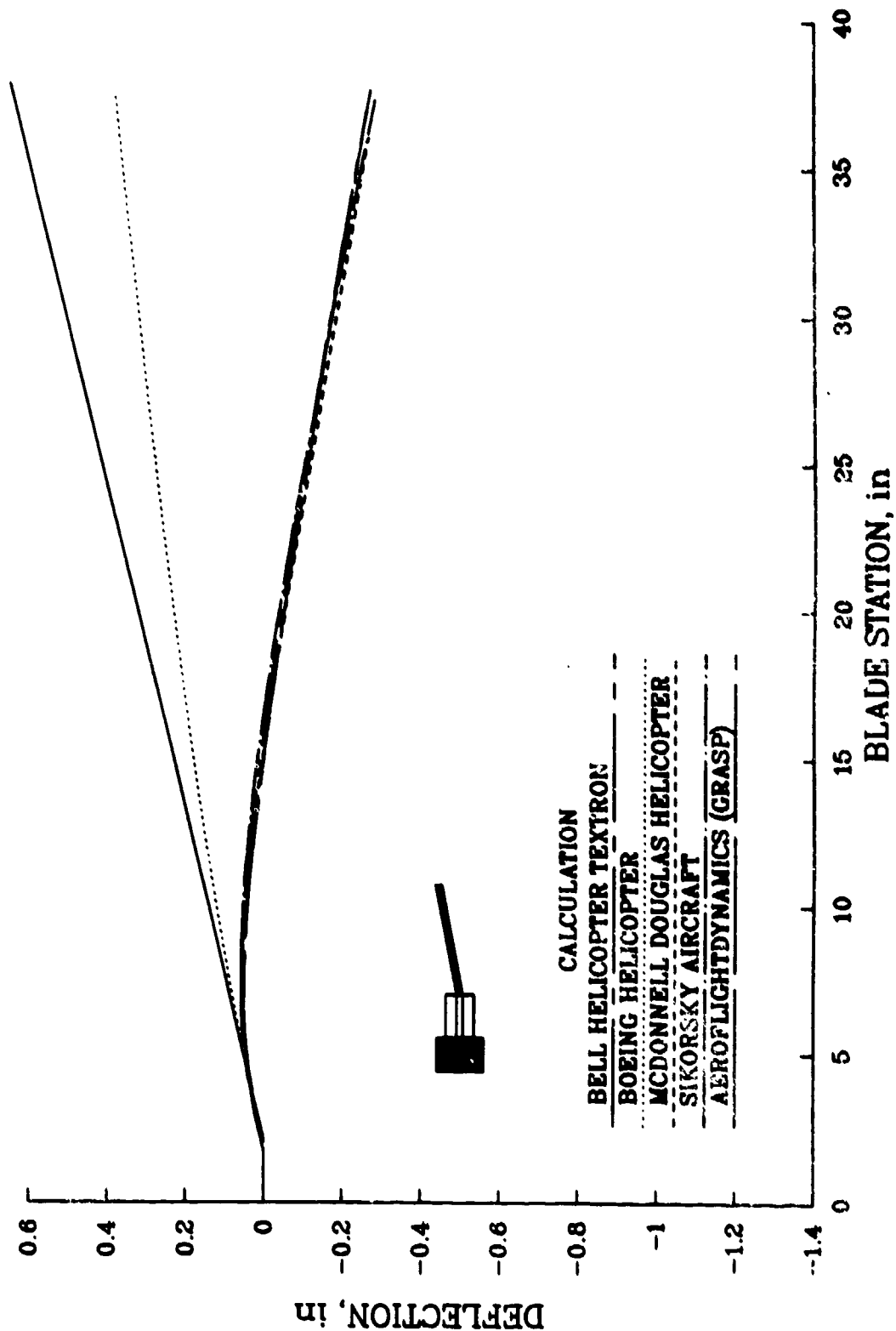




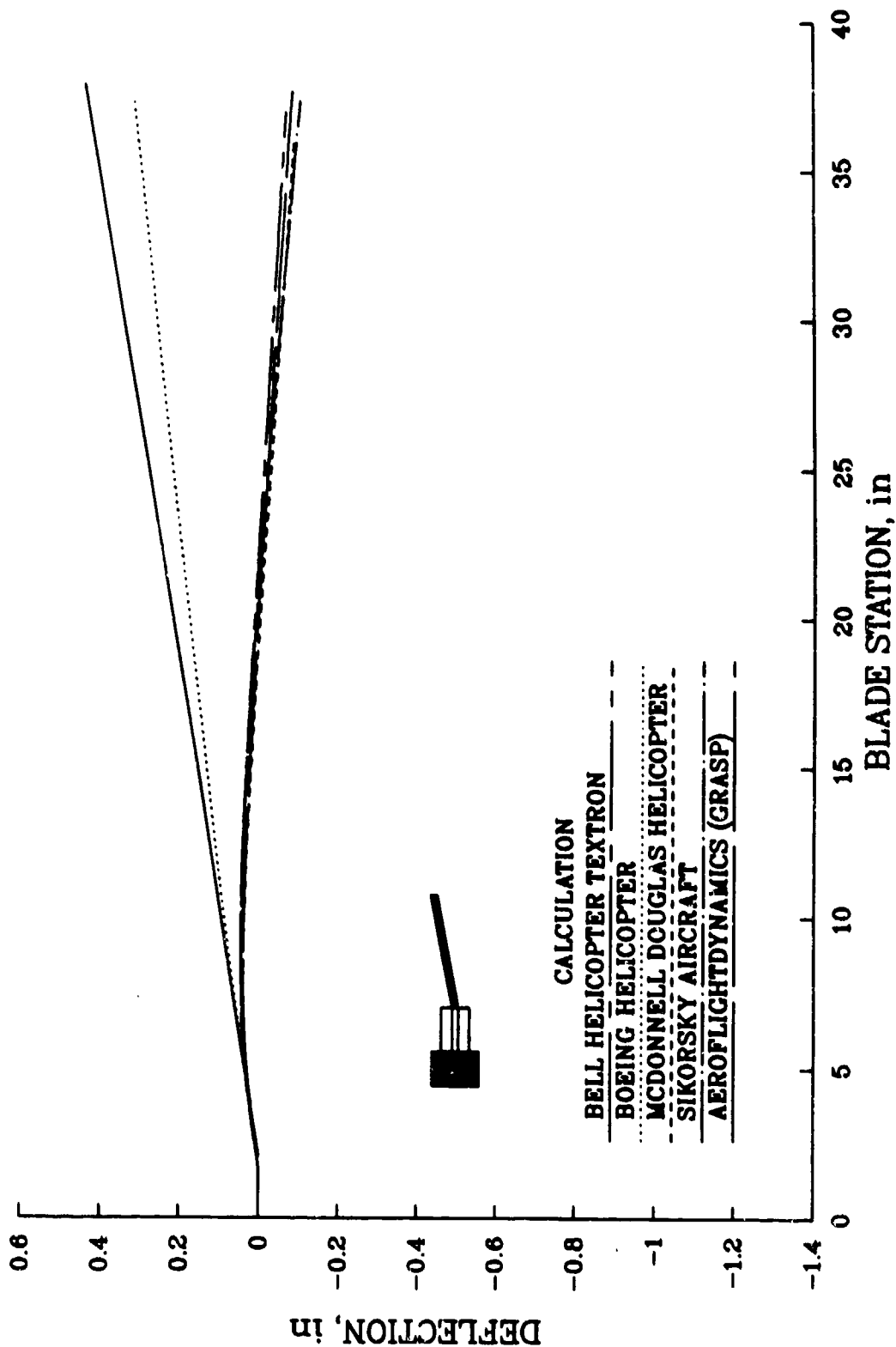
FLAP EQUILIBRIUM DEFLECTION - TASK 86f  
 NONLINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = 12 deg



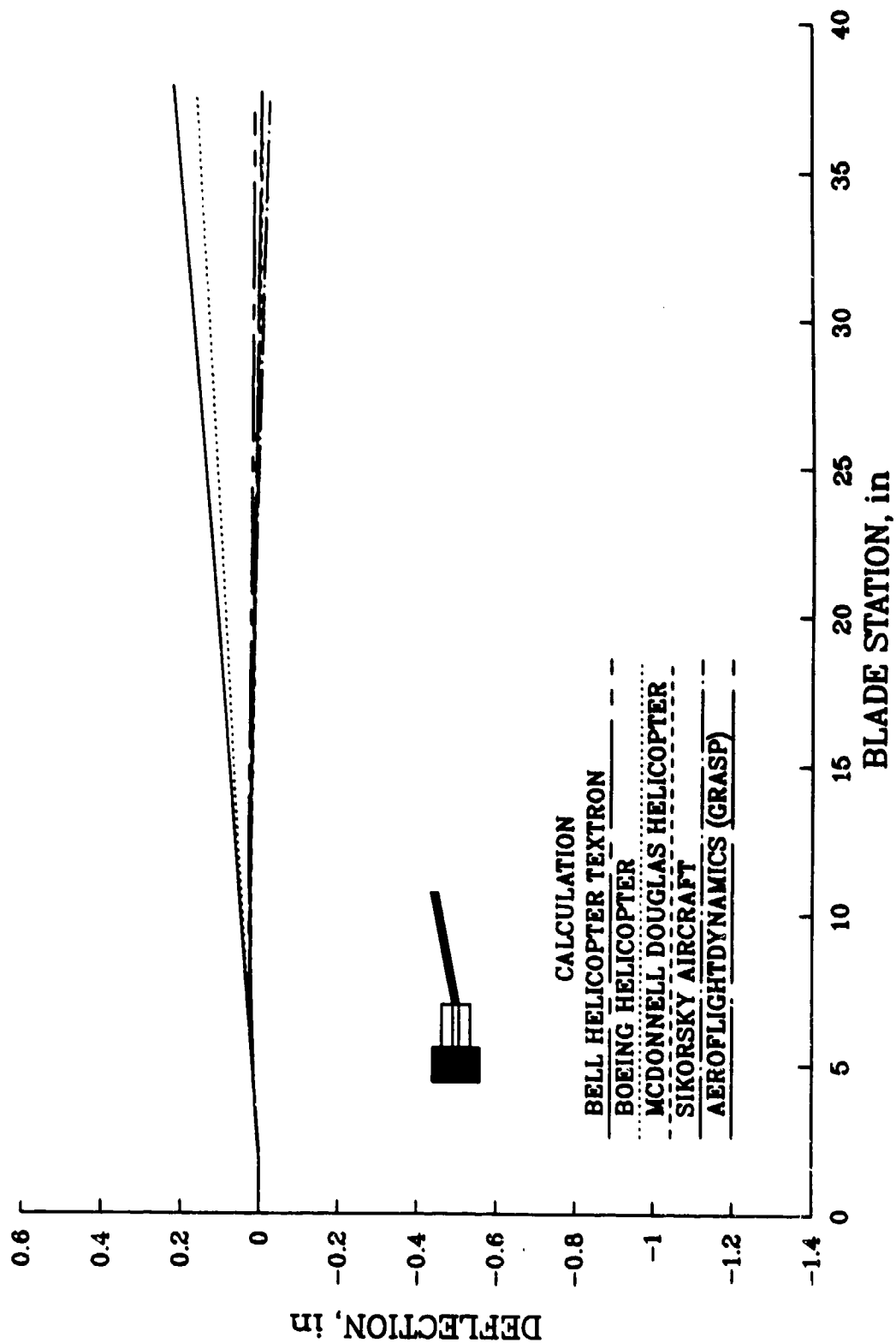
LEAD-LAG EQUILIBRIUM DEFLECTION - TASK 86f  
 NONLINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = -12 deg



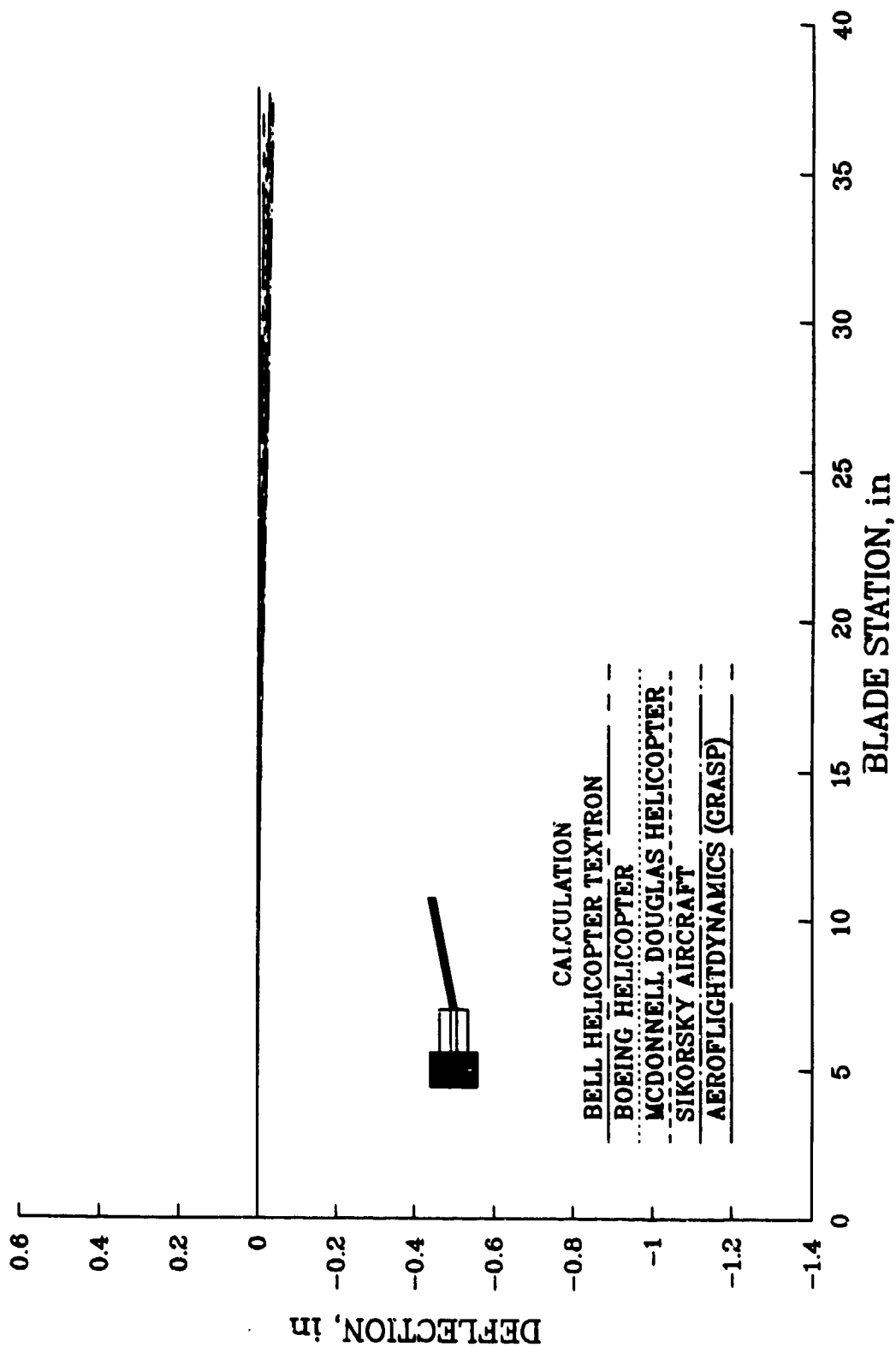
LEAD-LAG EQUILIBRIUM DEFLECTION - TASK 86f  
 NONLINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = -8 deg



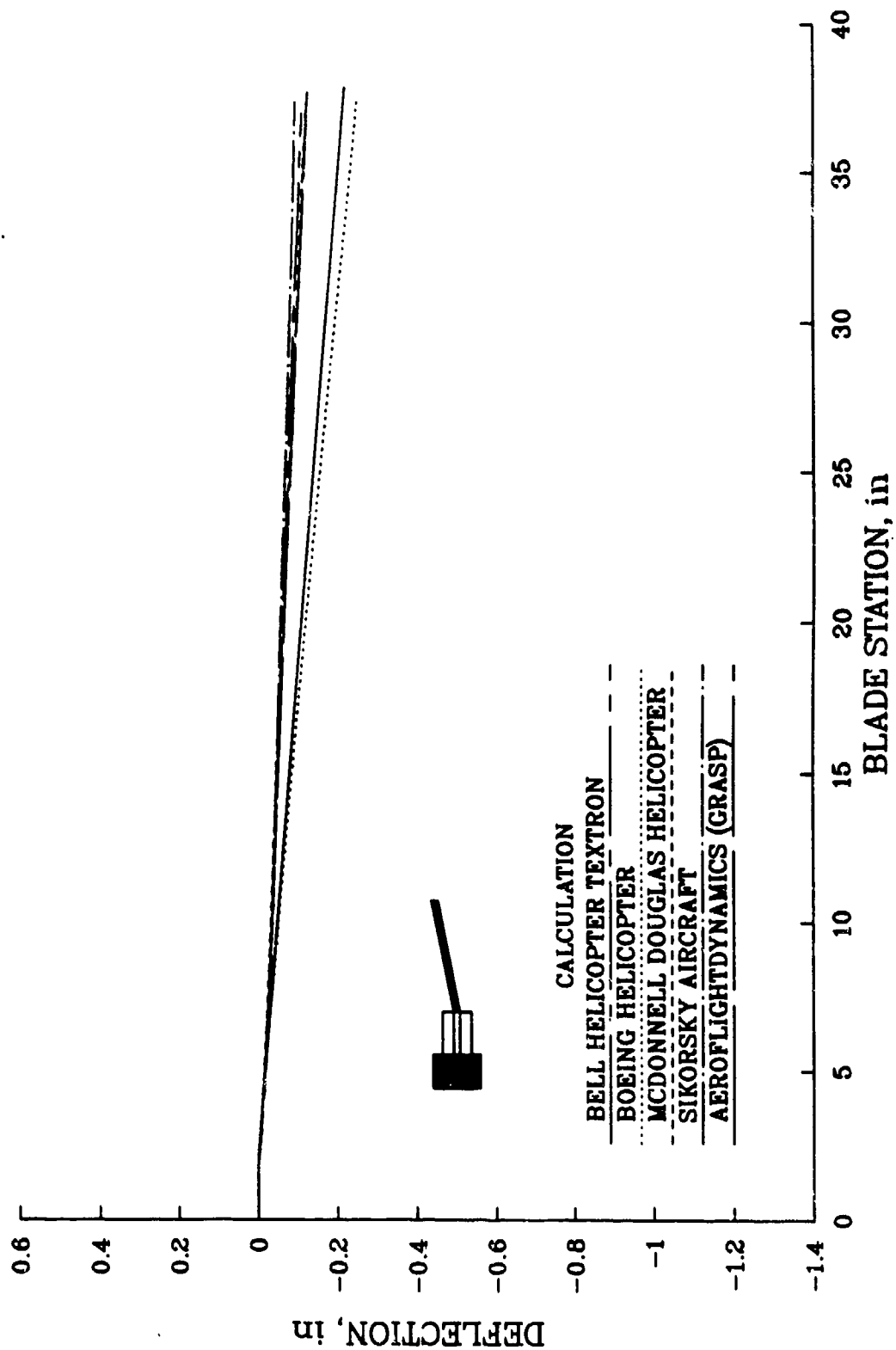
LEAD-LAG EQUILIBRIUM DEFLECTION - TASK 86f  
 NONLINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = -4 deg



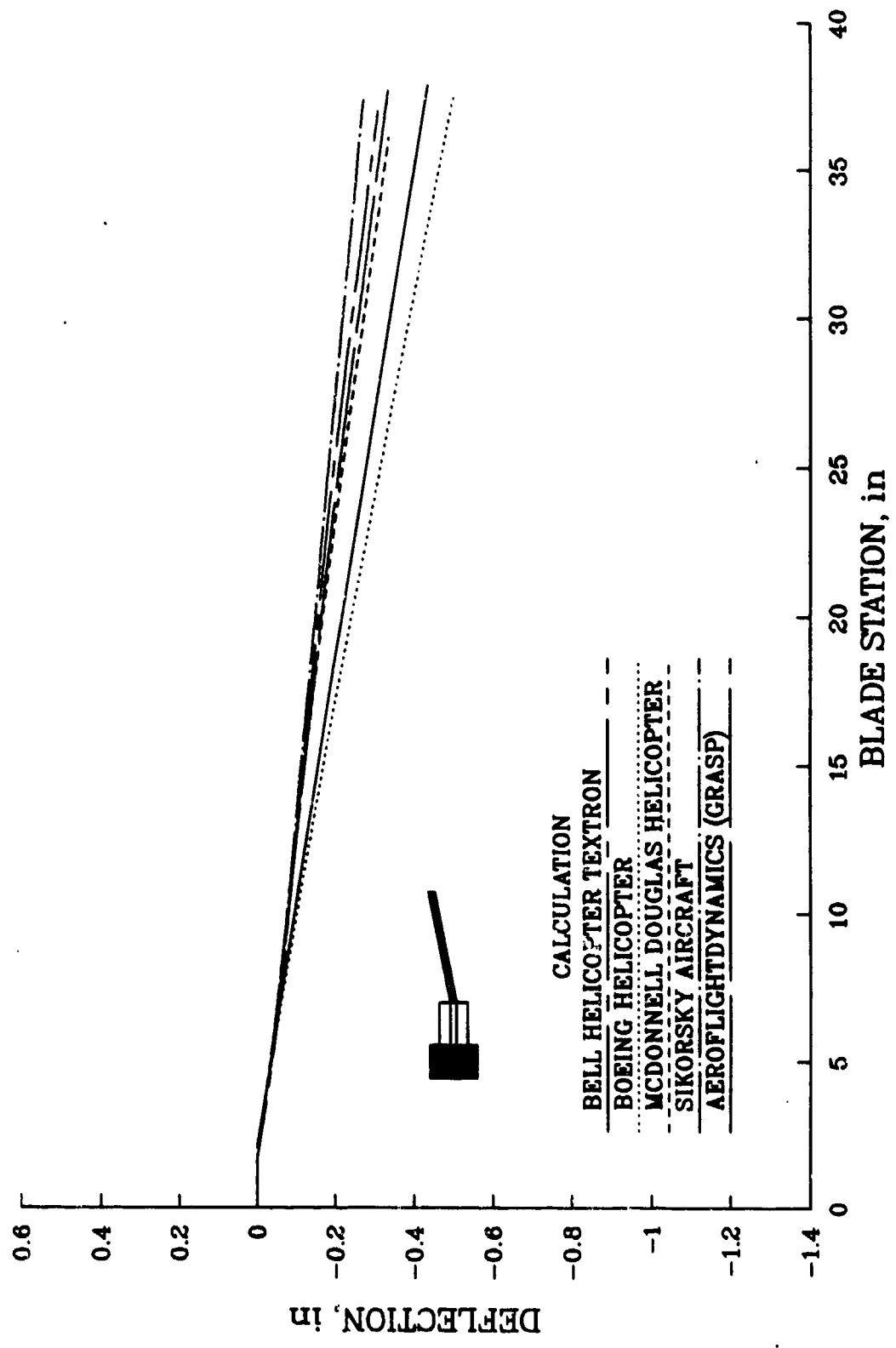
LEAD-LAG EQUILIBRIUM DEFLECTION - TASK 86f  
 NONLINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = 0 deg



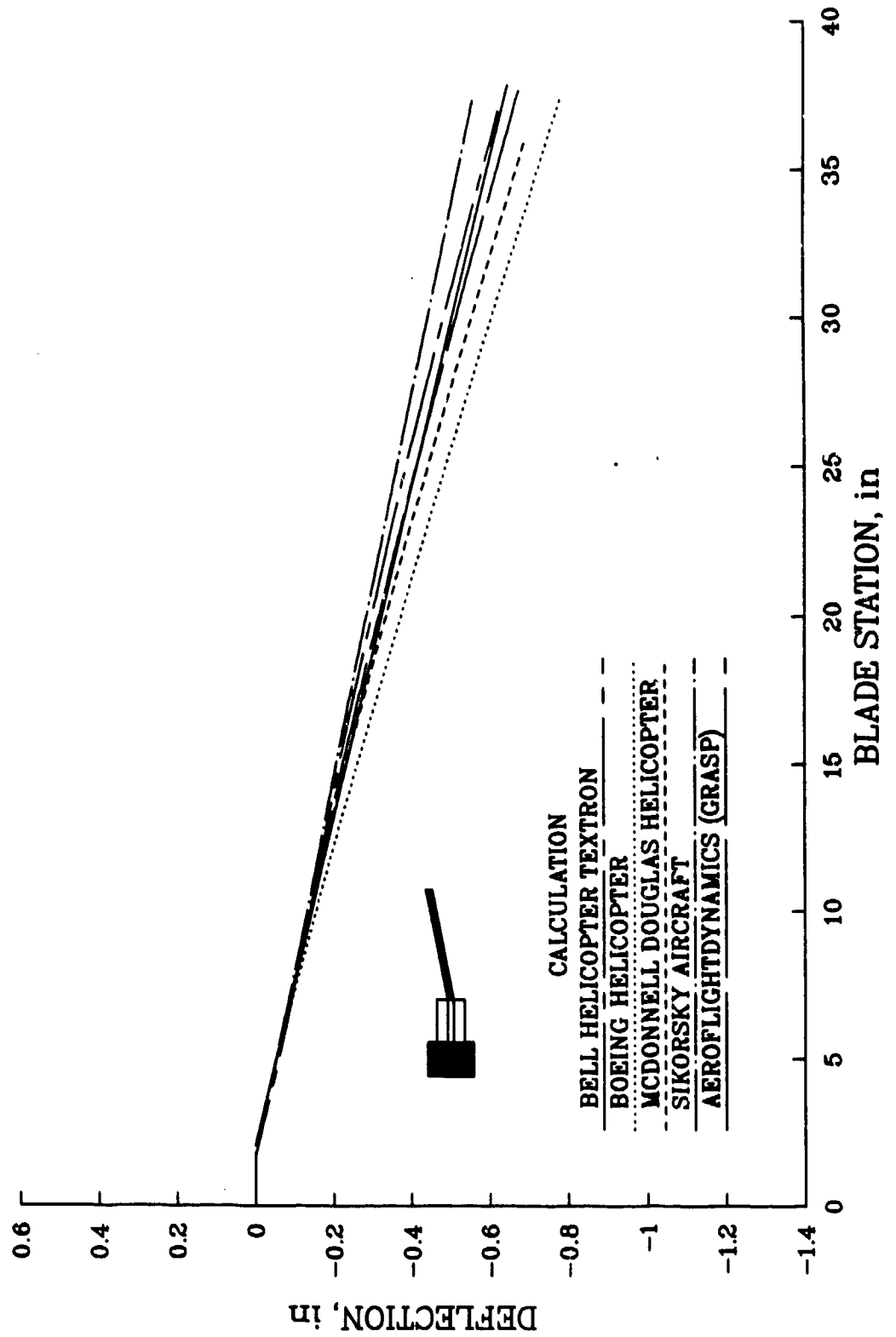
LEAD-LAG EQUILIBRIUM DEFLECTION - TASK 86f  
 NONLINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = 4 deg



LEAD-LAG EQUILIBRIUM DEFLECTION - TASK 86f  
 NONLINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = 8 deg

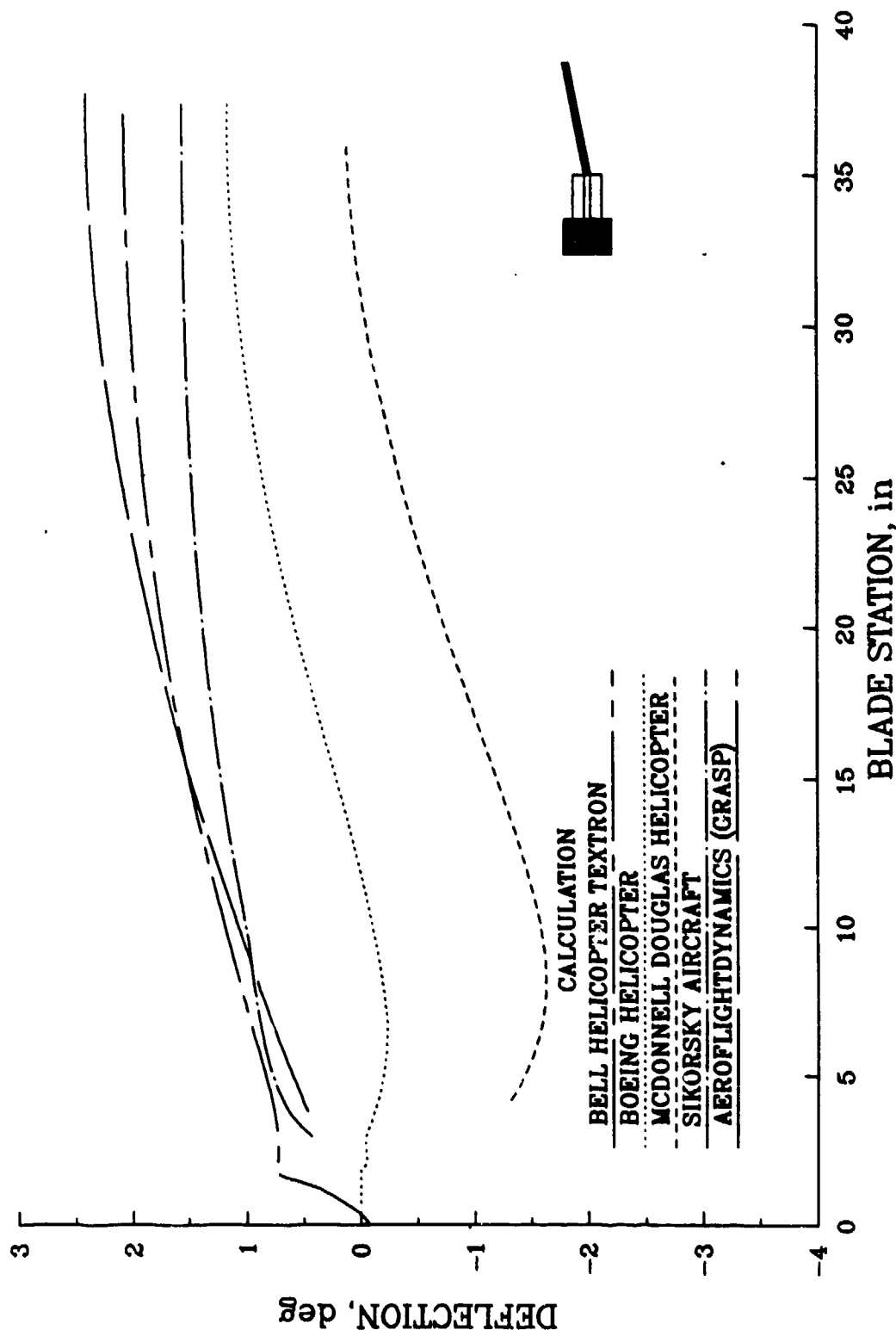


LEAD-LAG EQUILIBRIUM DEFLECTION - TASK 86f  
 NONLINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = 12 deg

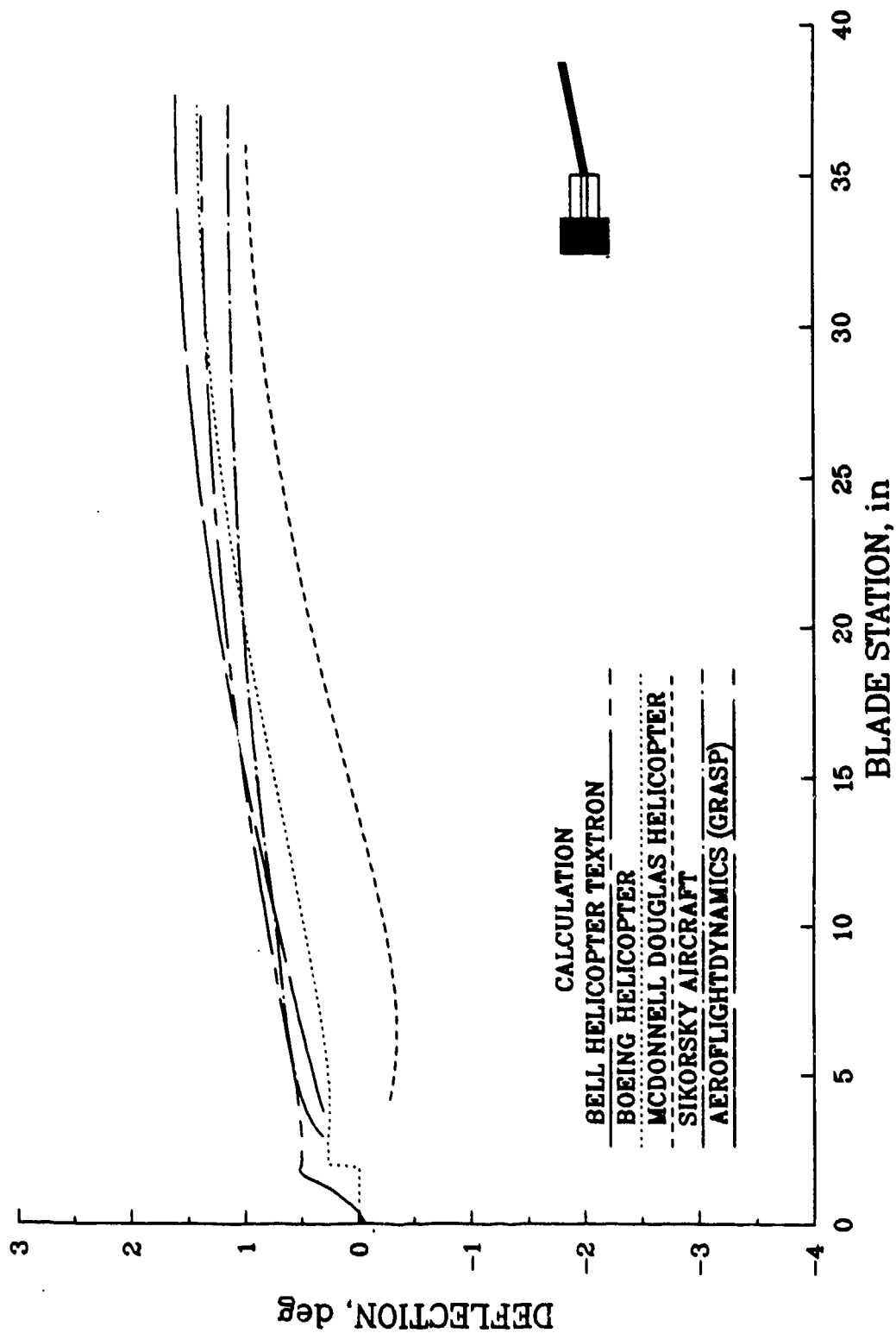




**TORSION EQUILIBRIUM DEFLECTION - TASK 86f**  
**NONLINEAR AERODYNAMIC COEFFICIENTS**  
**CASE 6 - TORSIONALLY SOFT ROTOR**  
**PITCH ANGLE = -12 deg**

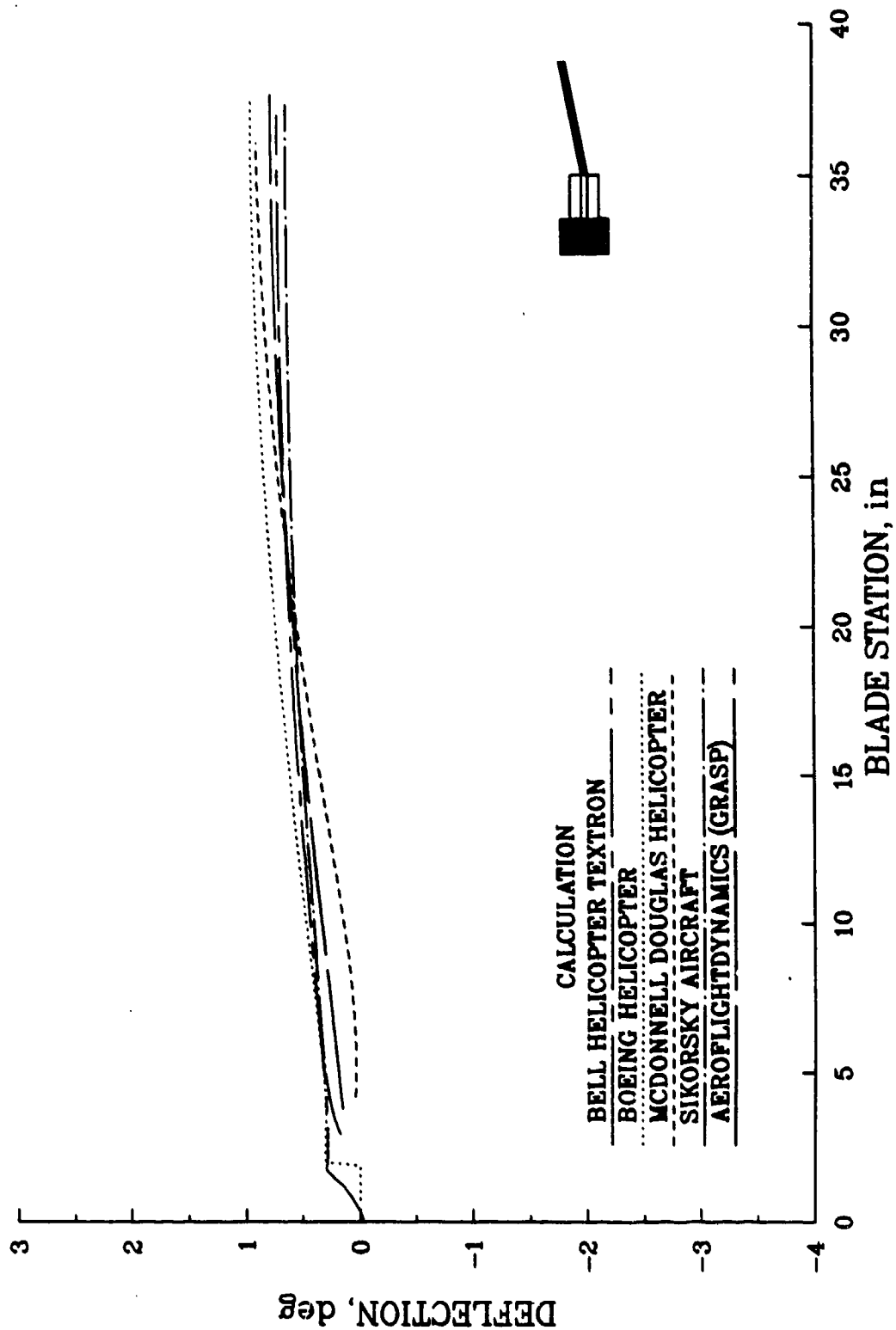


TORSION EQUILIBRIUM DEFLECTION - TASK 86f  
 NONLINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = -8 deg

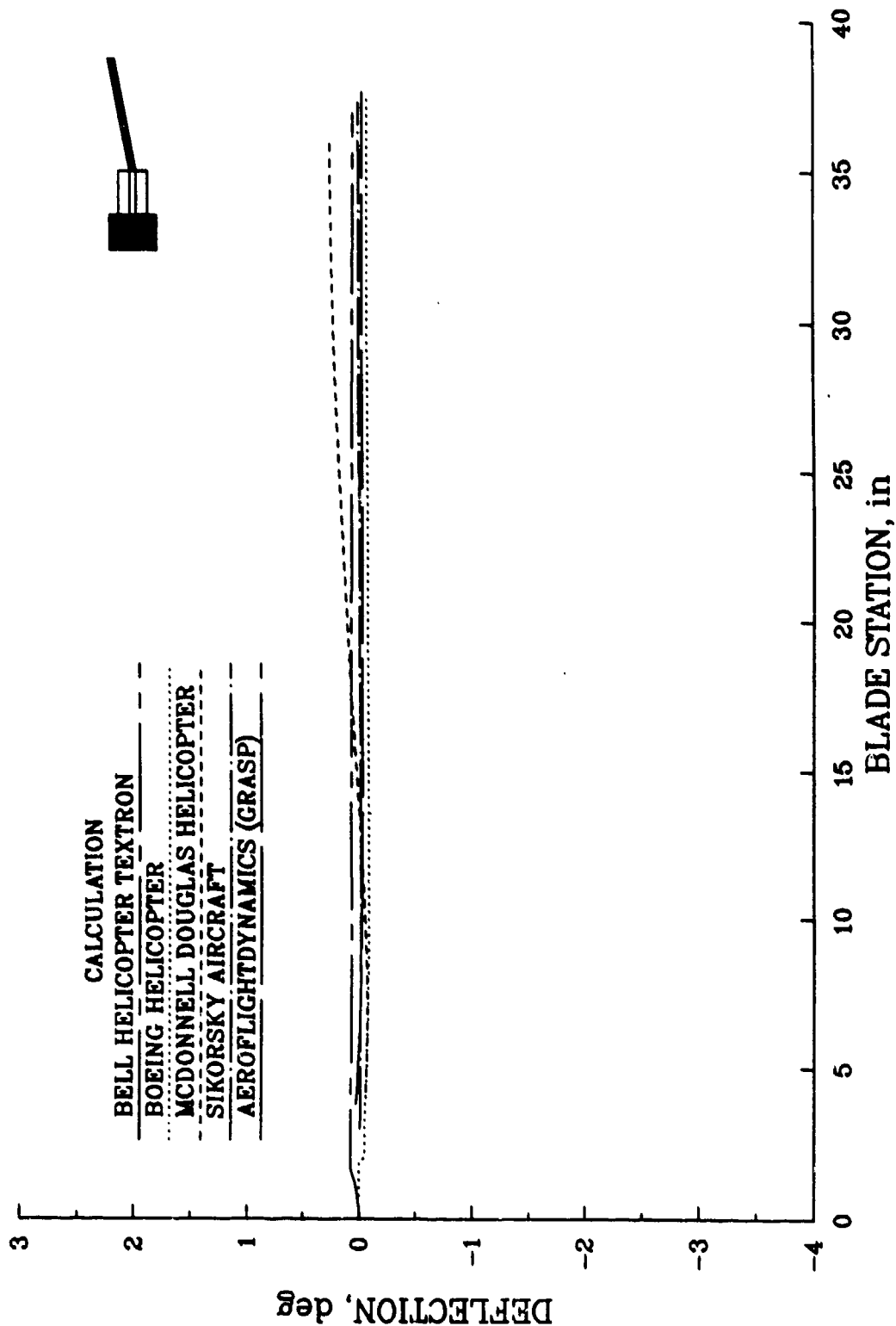


**TORSION EQUILIBRIUM DEFLECTION - TASK 86f**  
**NONLINEAR AERODYNAMIC COEFFICIENTS**  
**CASE 6 - TORSIONALLY SOFT ROTOR**

PITCH ANGLE = -4 deg

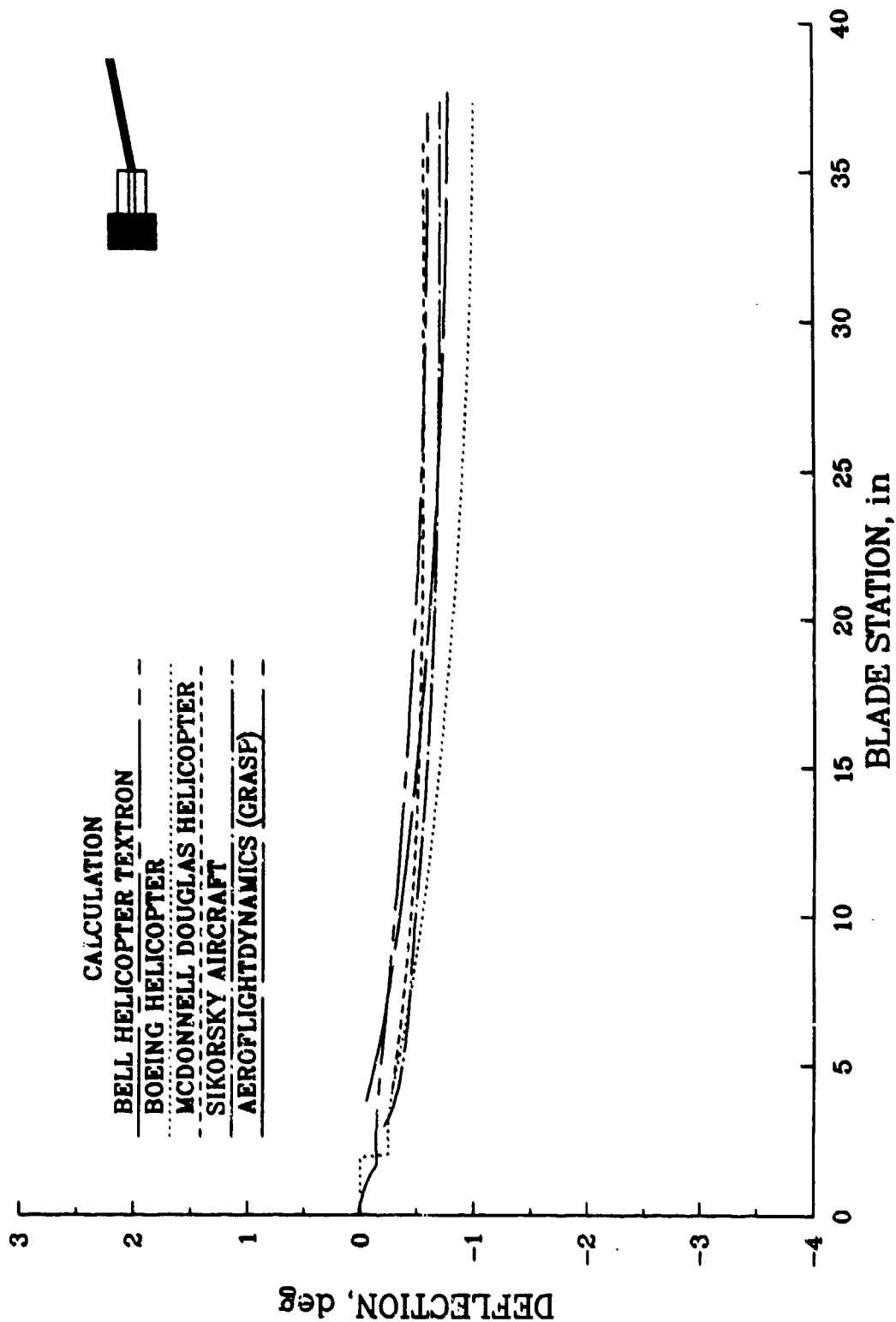


TORSION EQUILIBRIUM DEFLECTION - TASK 86f  
 NONLINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = 0 deg



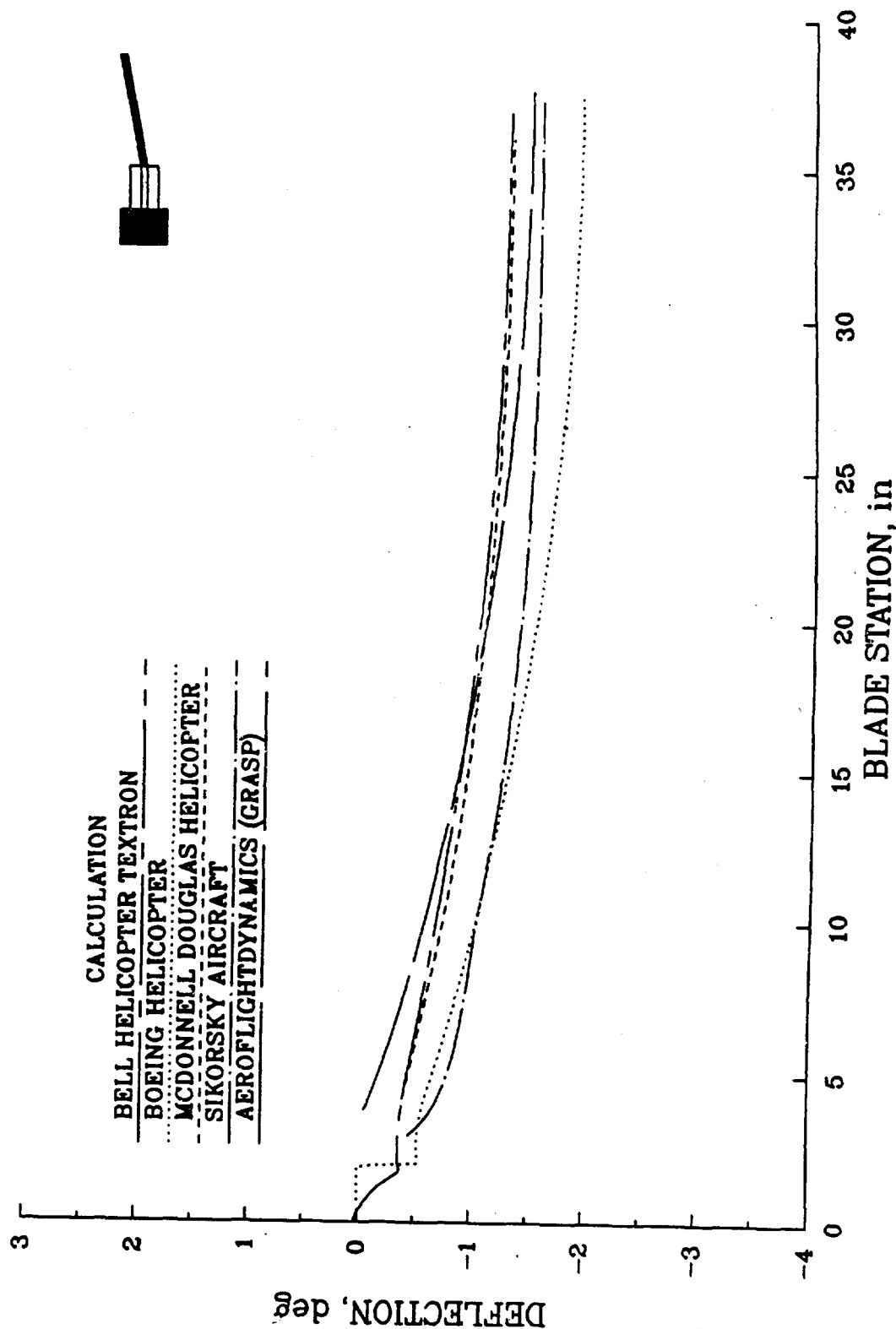
TORSION EQUILIBRIUM DEFLECTION - TASK 86f  
 NONLINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR

PITCH ANGLE = 4 deg



TORSION EQUILIBRIUM DEFLECTION - TASK 86f  
 NONLINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR

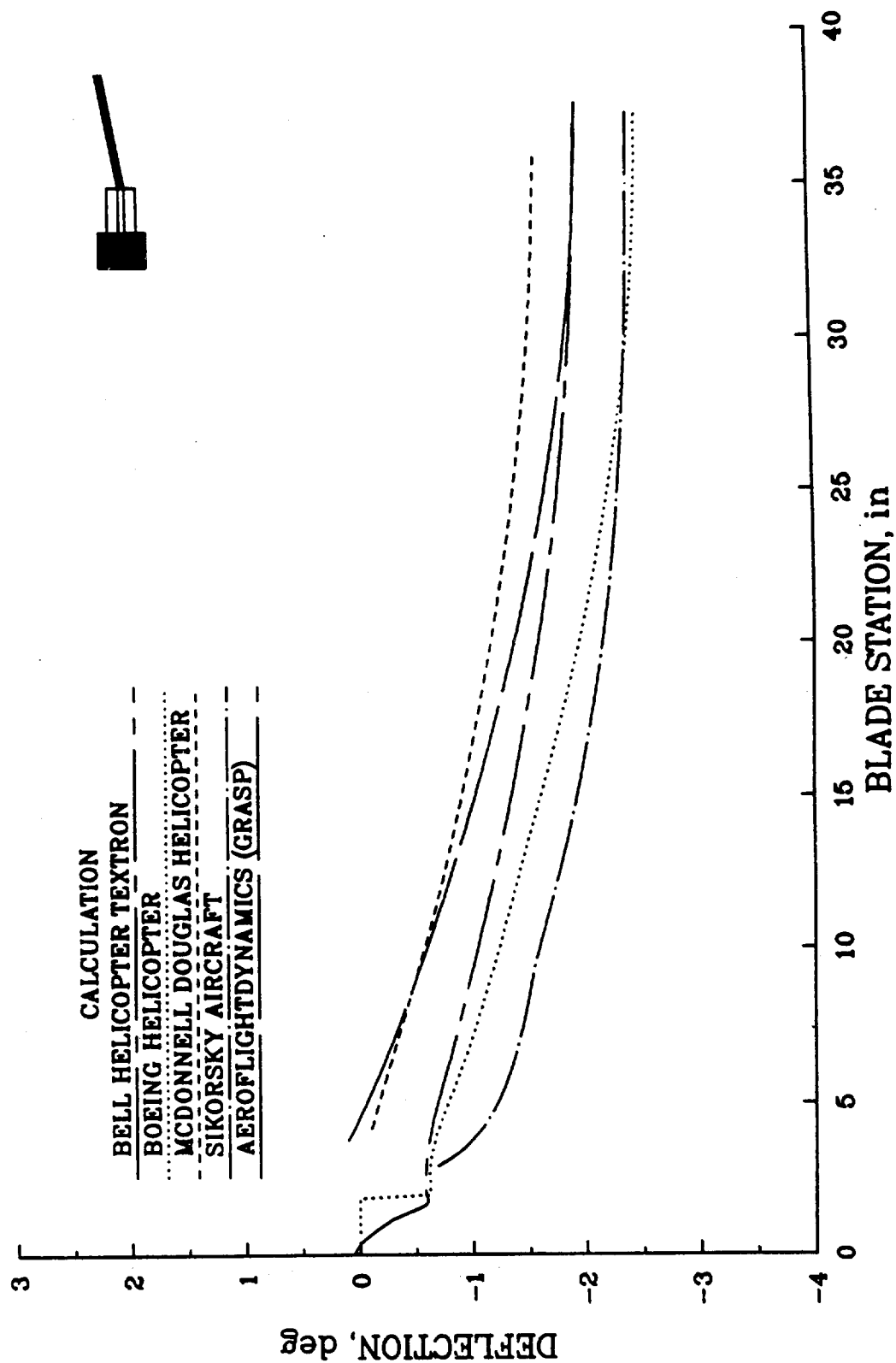
PITCH ANGLE = 8 deg



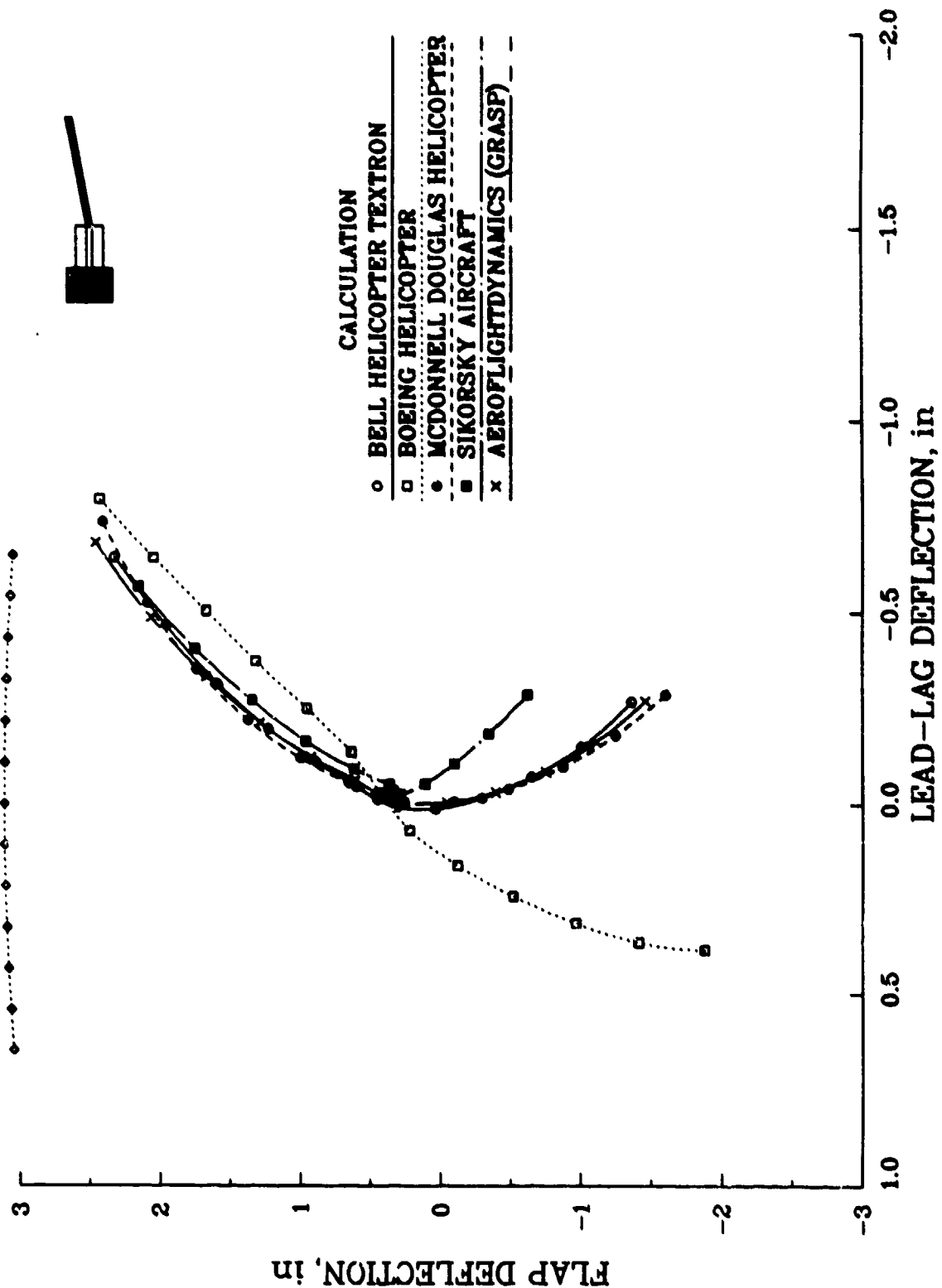
TORSION EQUILIBRIUM DEFLECTION - TASK 86f  
NONLINEAR AERODYNAMIC COEFFICIENTS

CASE 6 - TORSIONALLY SOFT ROTOR

PITCH ANGLE = 12 deg

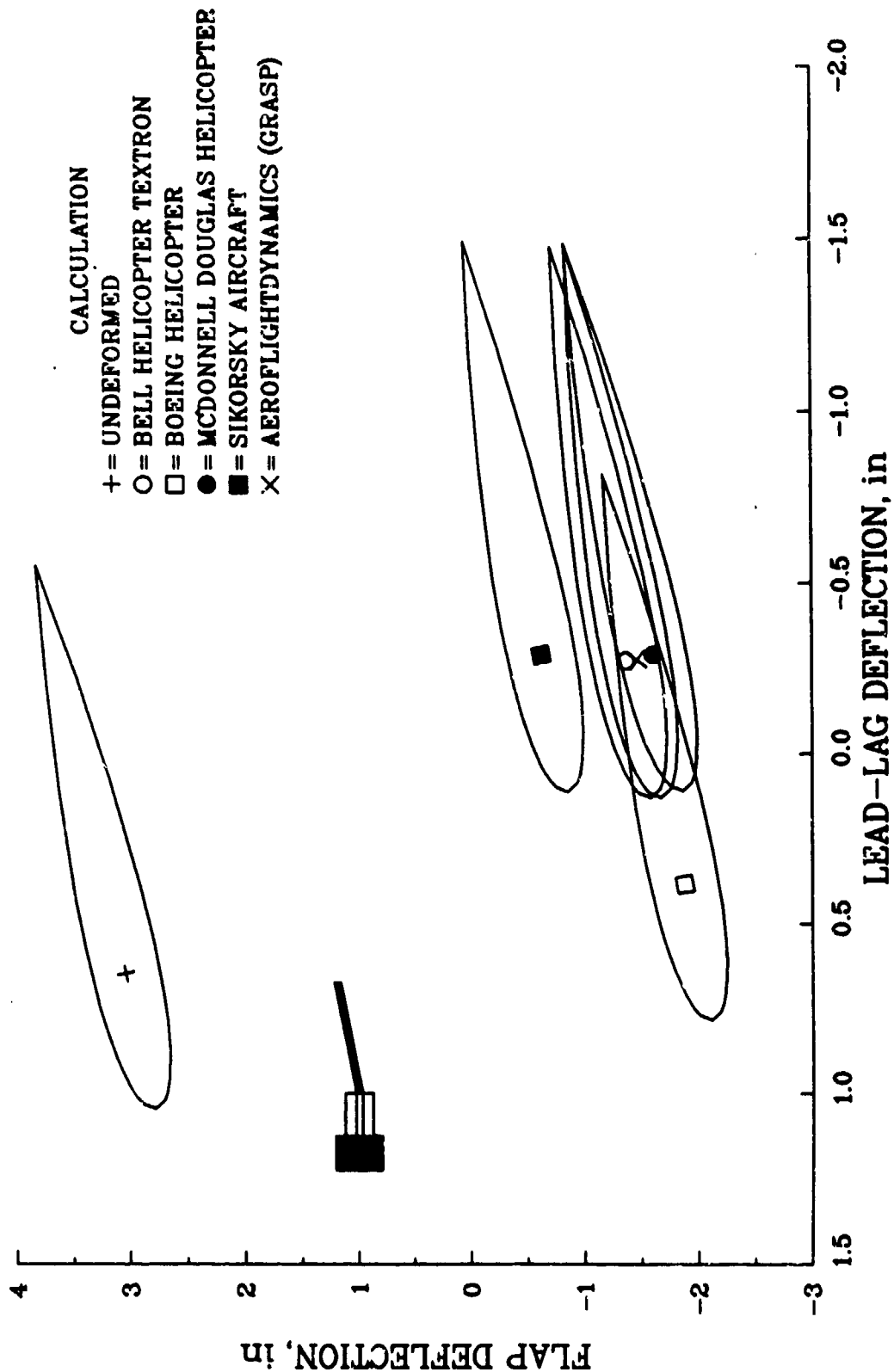


BLADE TIP DEFLECTION - TASK 86f  
NONLINEAR AERODYNAMIC COEFFICIENTS  
CASE 6 - TORSIONALLY SOFT ROTOR



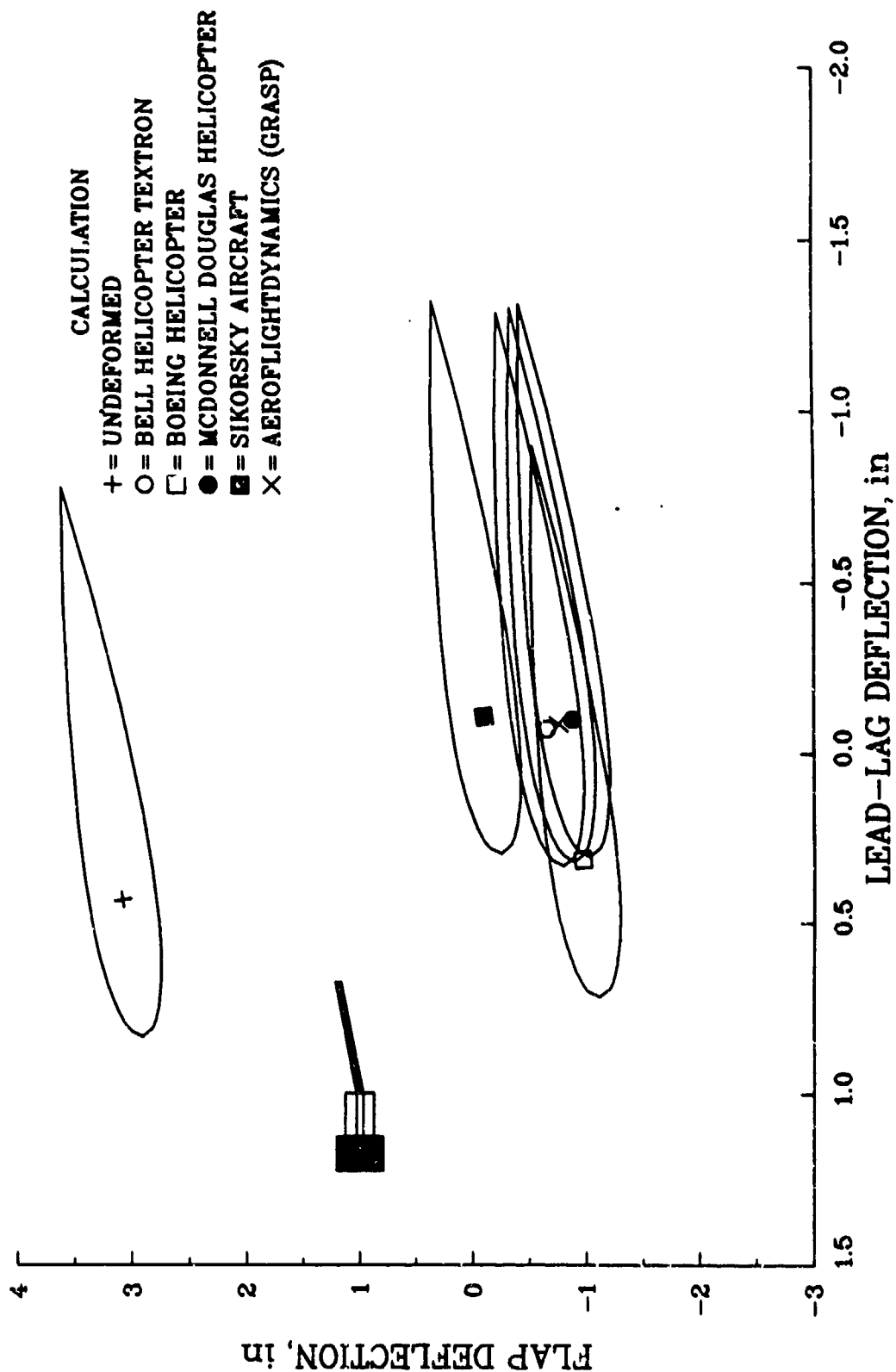


BLADE TIP DEFLECTION - TASK 86f  
 NONLINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = -12 deg



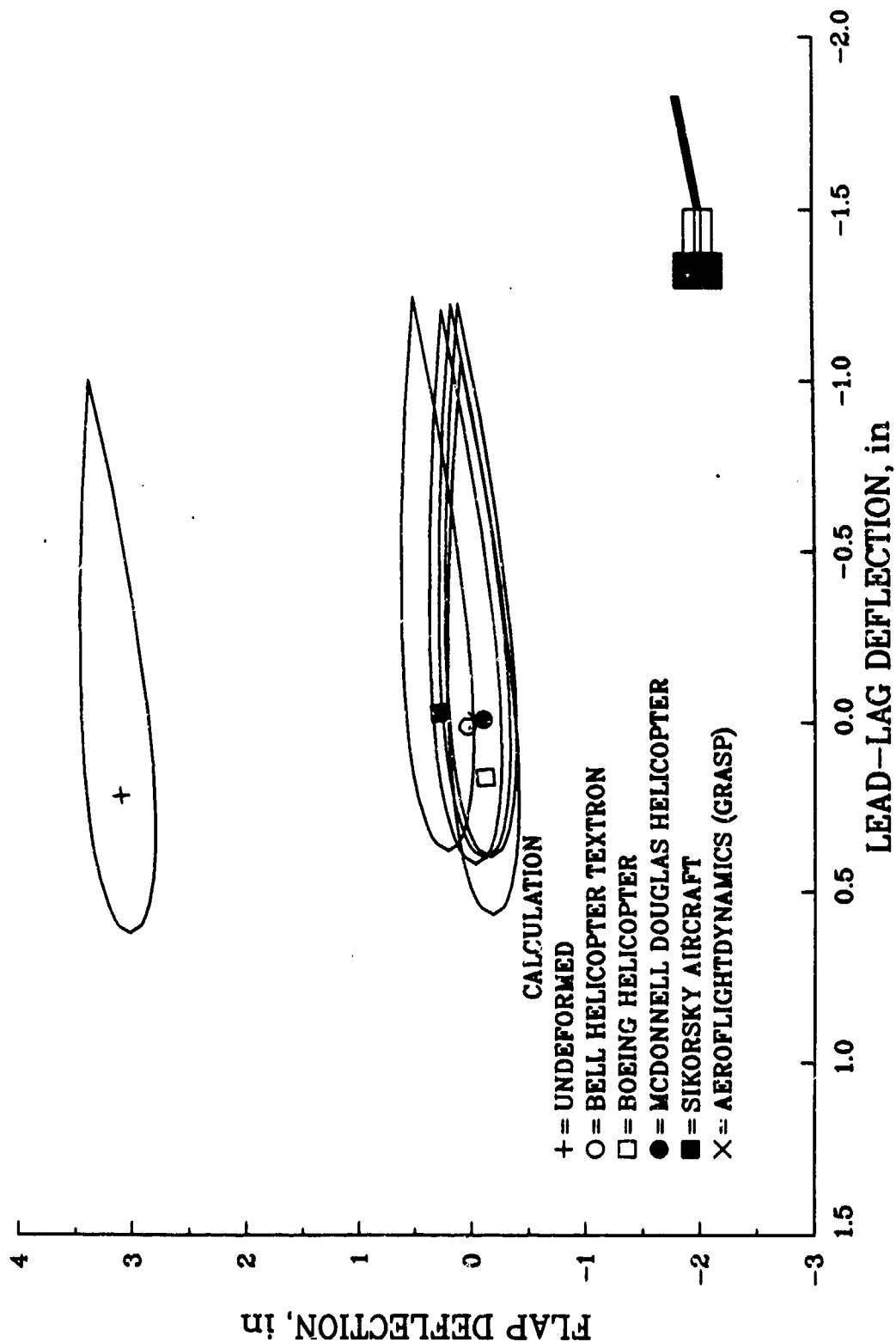
BLADE TIP DEFLECTION - TASK 86f  
 NONLINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR

PITCH ANGLE = -8 deg

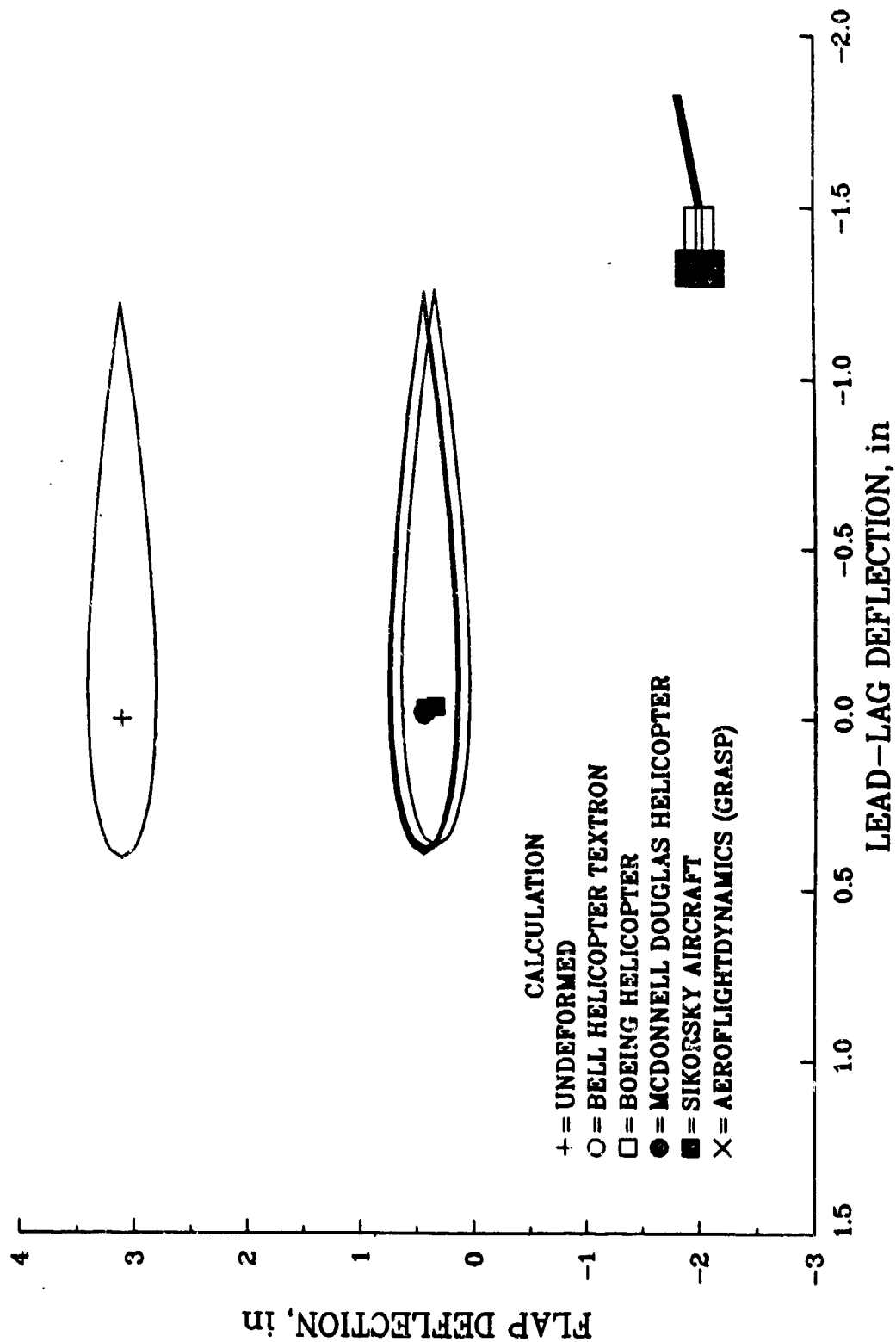


BLADE TIP DEFLECTION - TASK 86f  
 NONLINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR

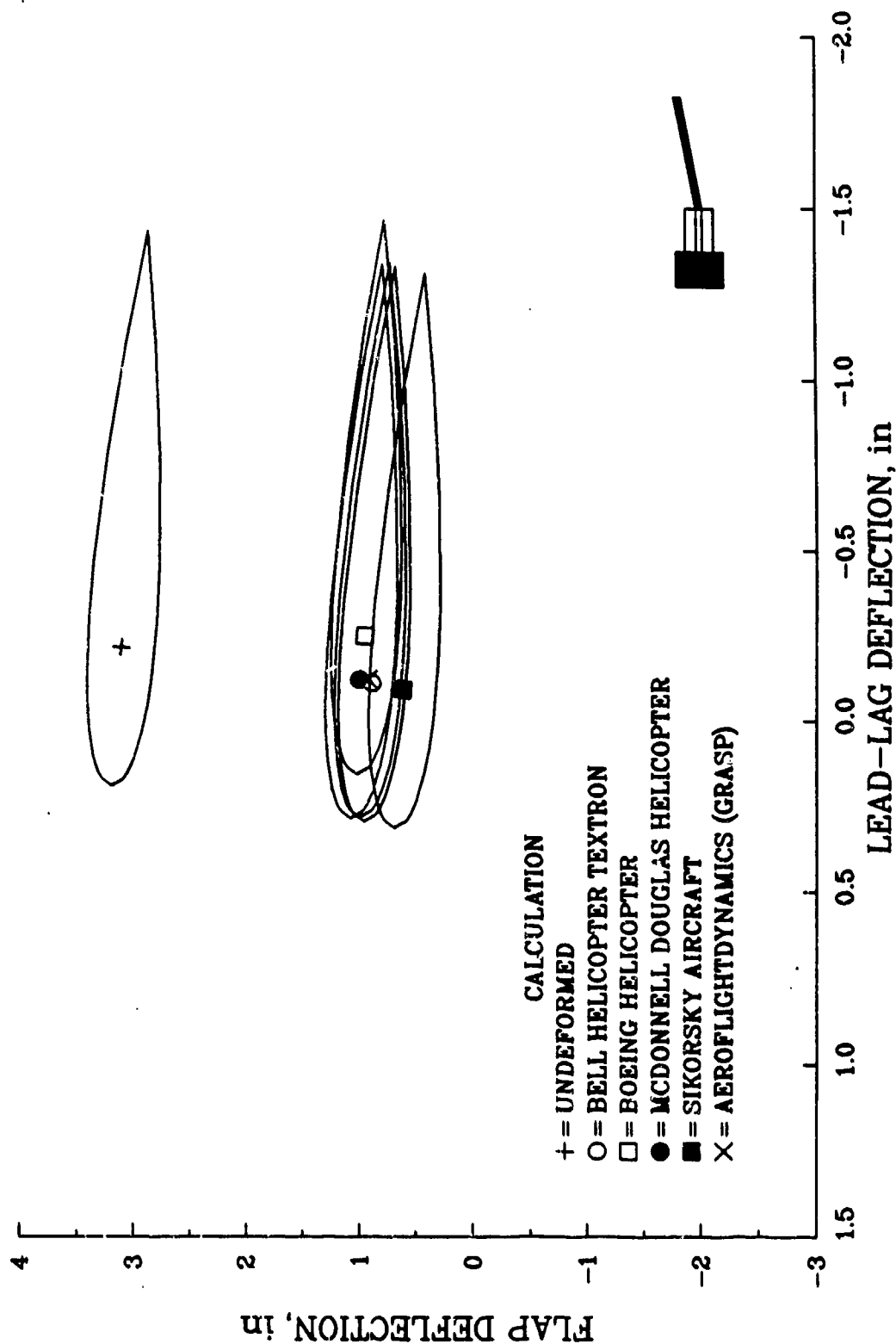
PITCH ANGLE = -4 deg



BLADE TIP DEFLECTION - TASK 86f  
 NONLINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = 0 deg

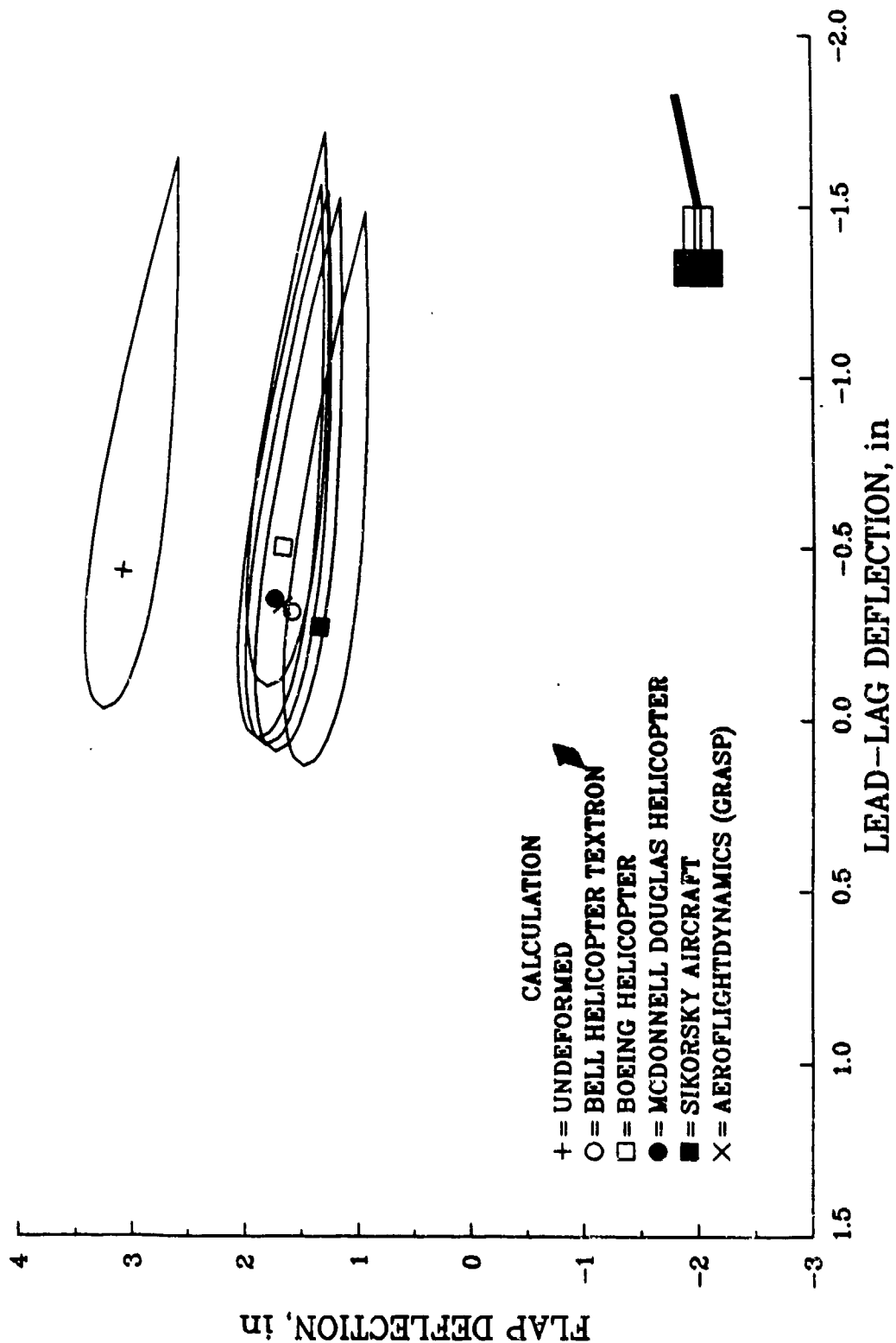


BLADE TIP DEFLECTION - TASK 86f  
 NONLINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = 4 deg

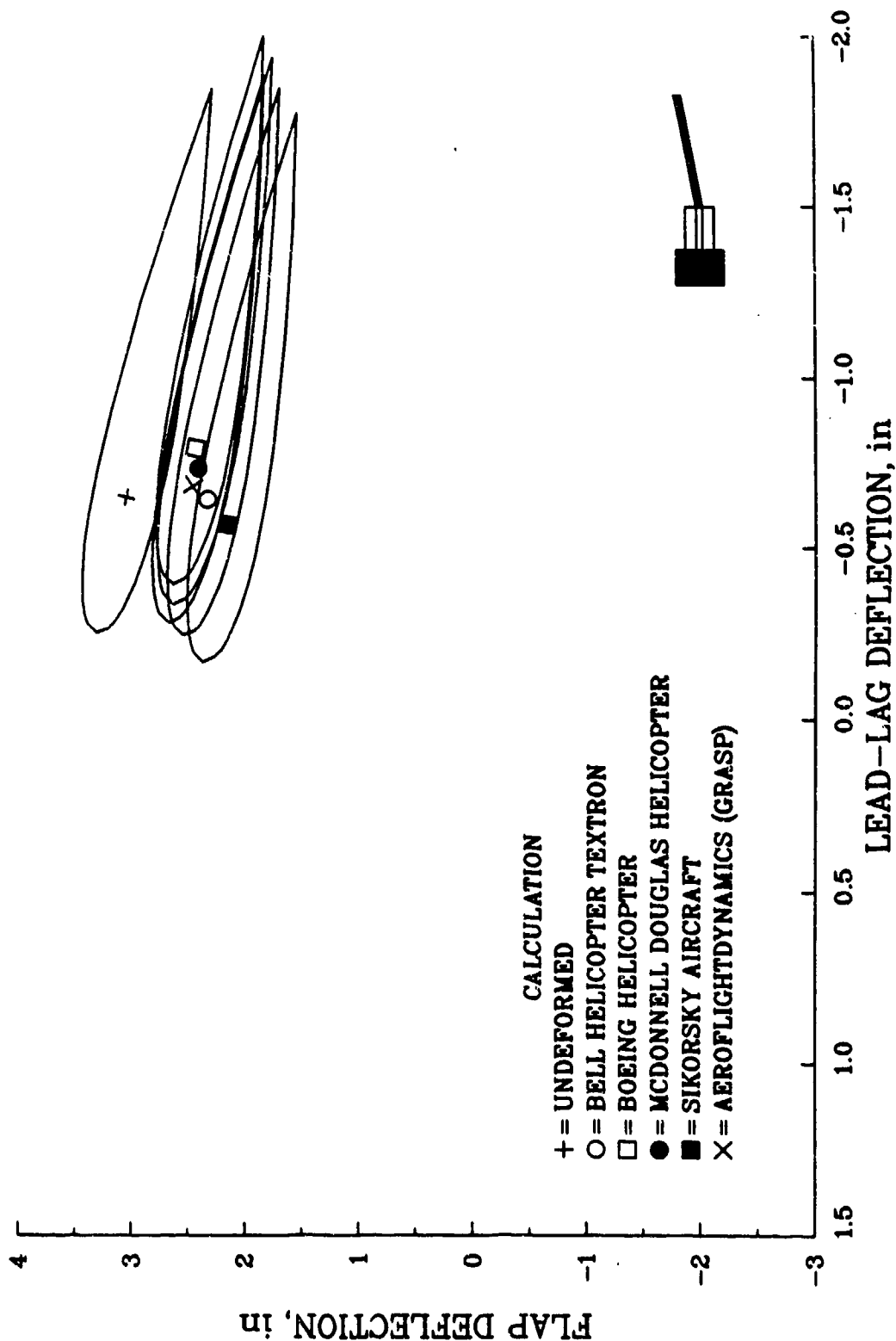


BLADE TIP DEFLECTION - TASK 86f  
 NONLINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR

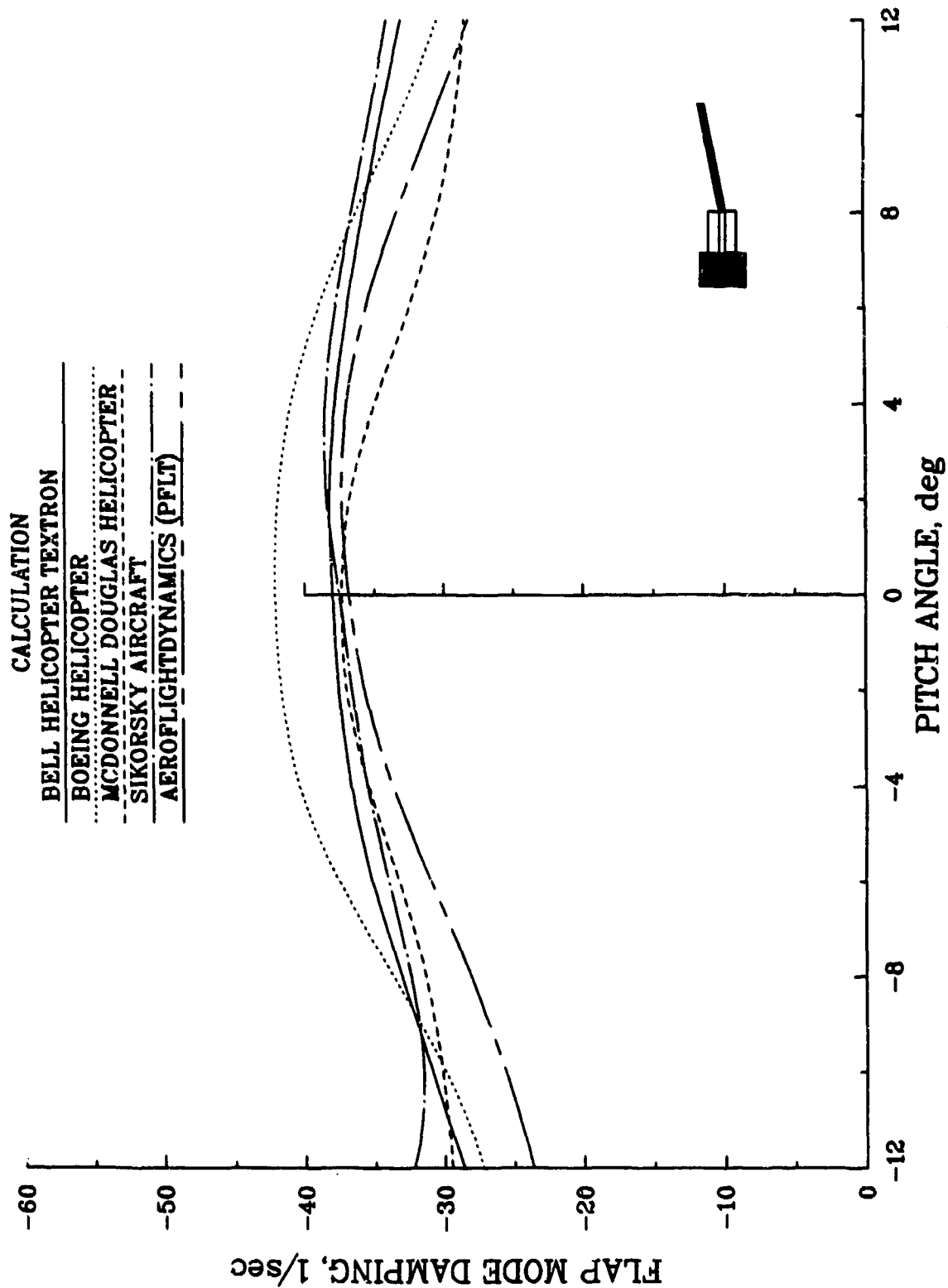
PITCH ANGLE = 8 deg



BLADE TIP DEFLECTION - TASK 86f  
 NONLINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = 12 deg

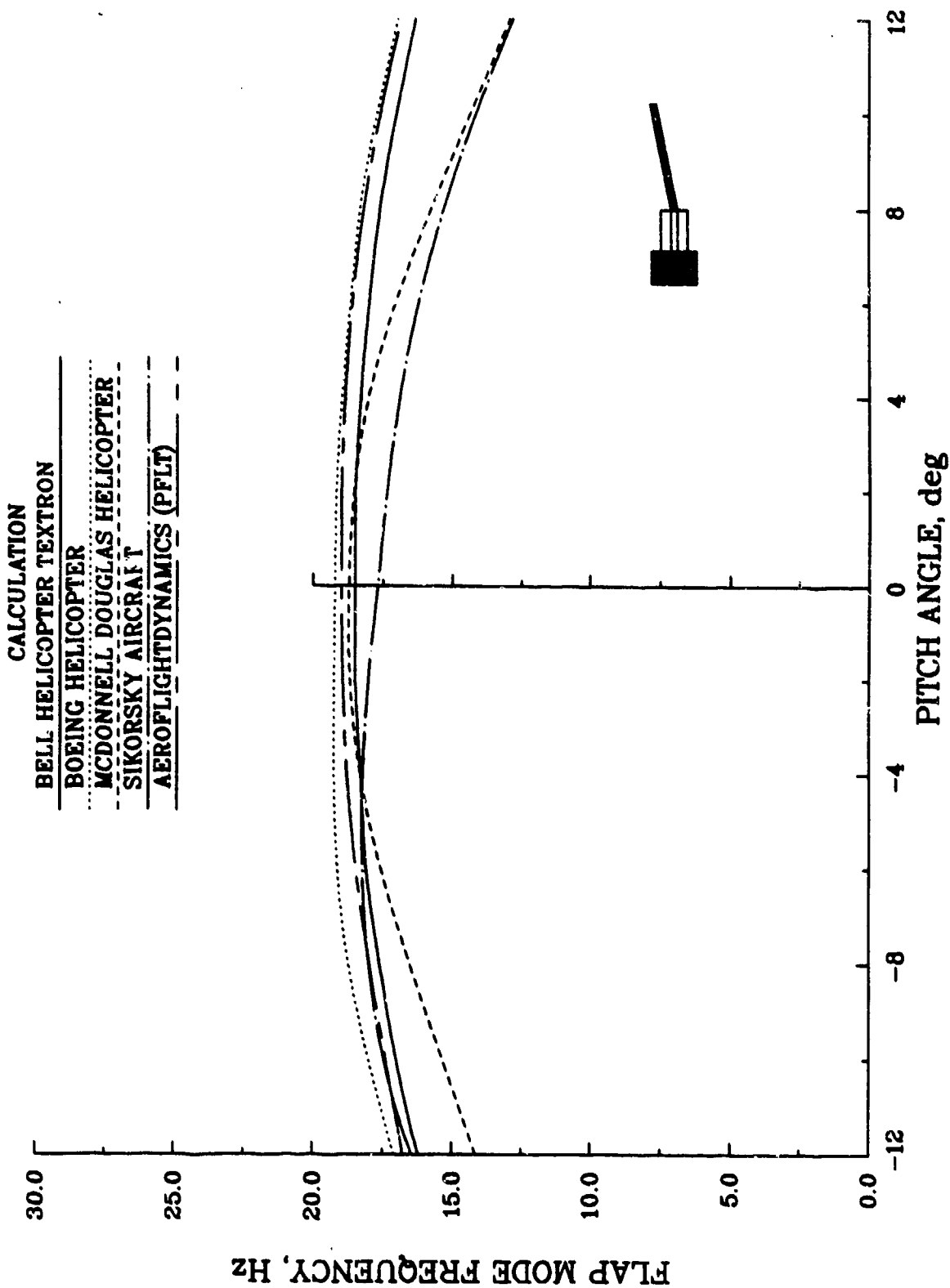


FLAP MODE DAMPING - TASK 86g  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR

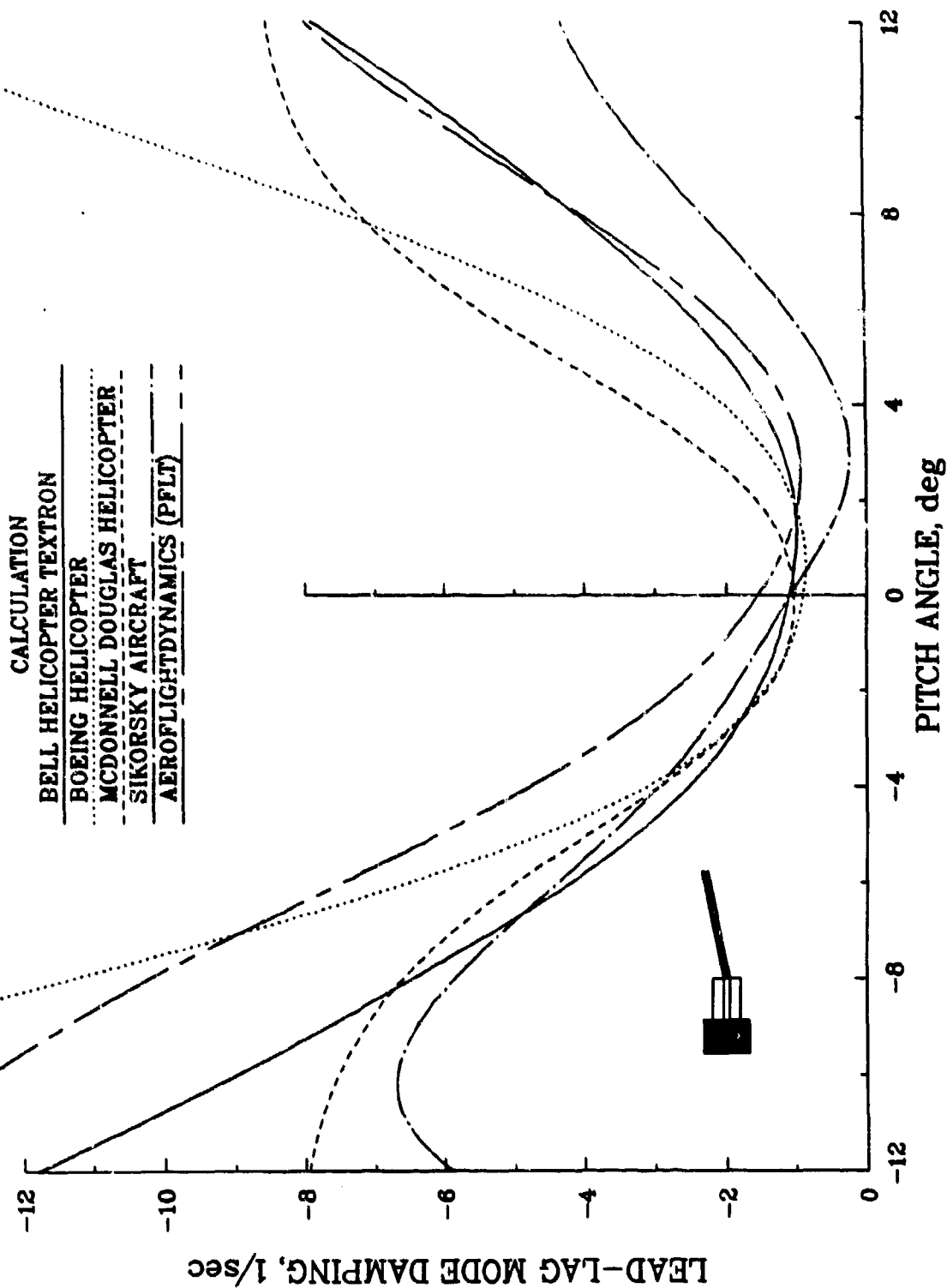




FLAP MODE FREQUENCY - TASK 86g  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR



LEAD-LAG MODE DAMPING - TASK 86g  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR



# LEAD-LAG MODE FREQUENCY - TASK 86g LINEAR AERODYNAMIC COEFFICIENTS CASE 6 - TORSIONALLY SOFT ROTOR

## CALCULATION

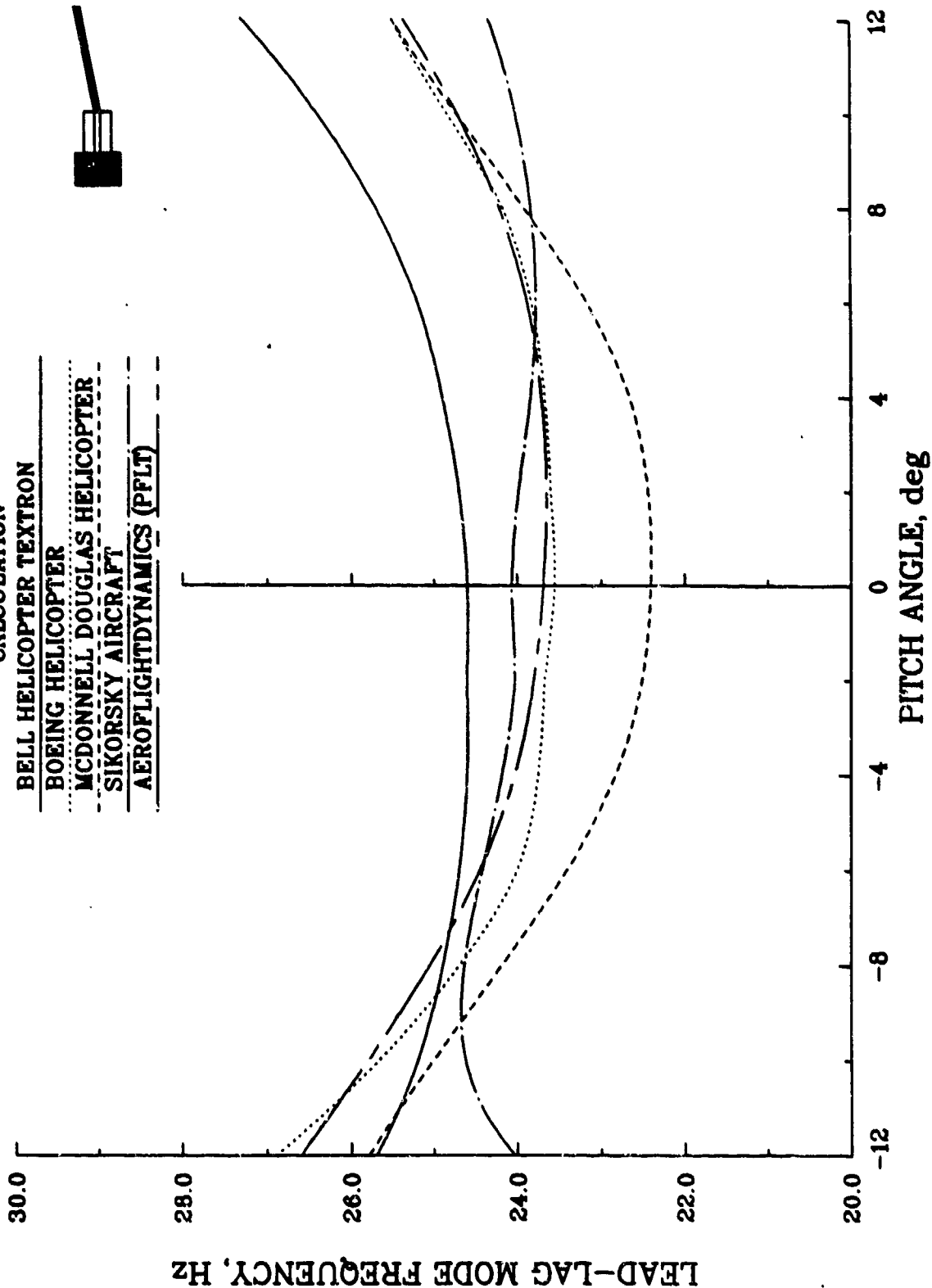
BELL HELICOPTER TEXTRON

BOEING HELICOPTER

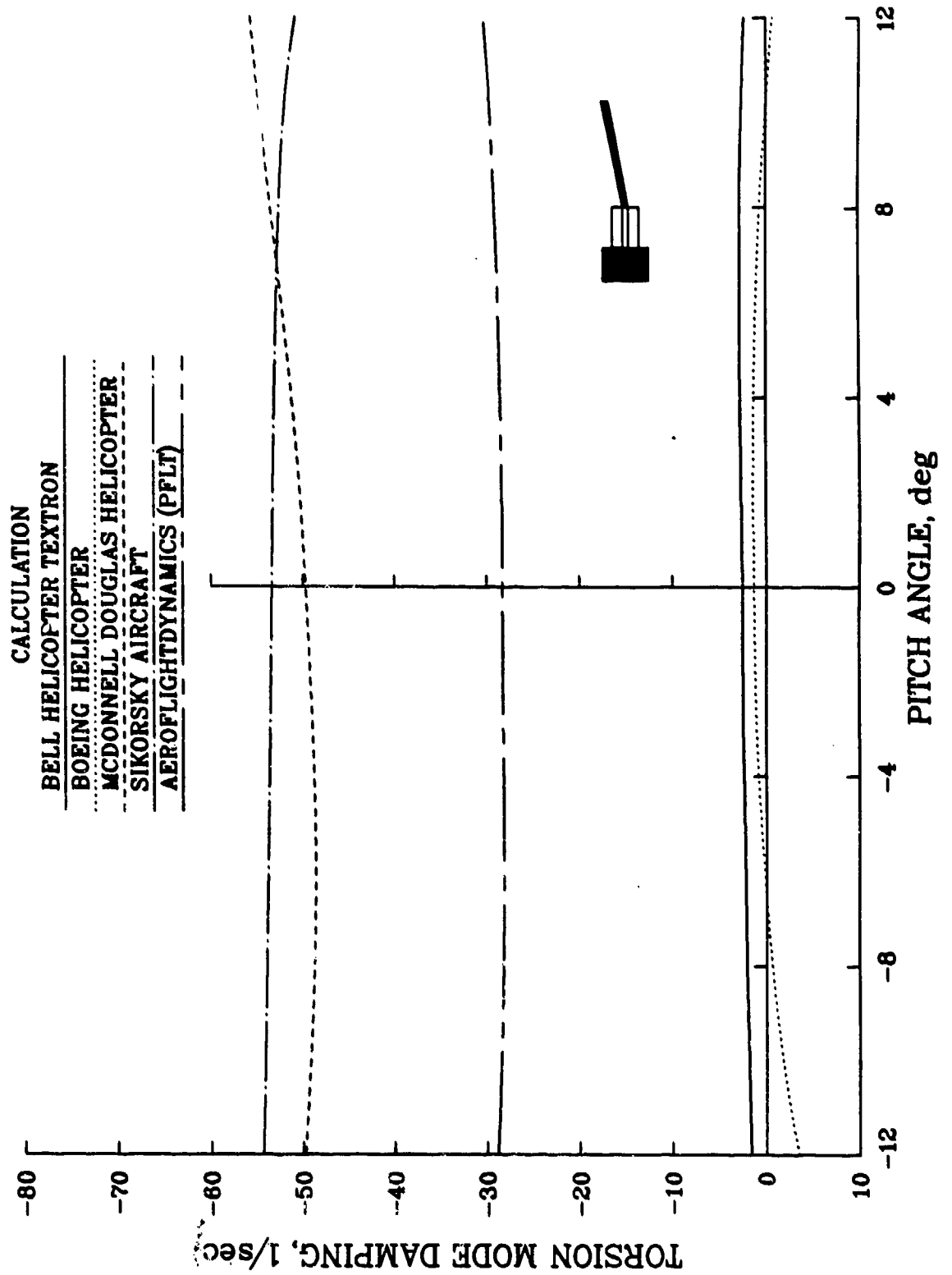
MCDONNELL DOUGLAS HELICOPTER

SIKORSKY AIRCRAFT

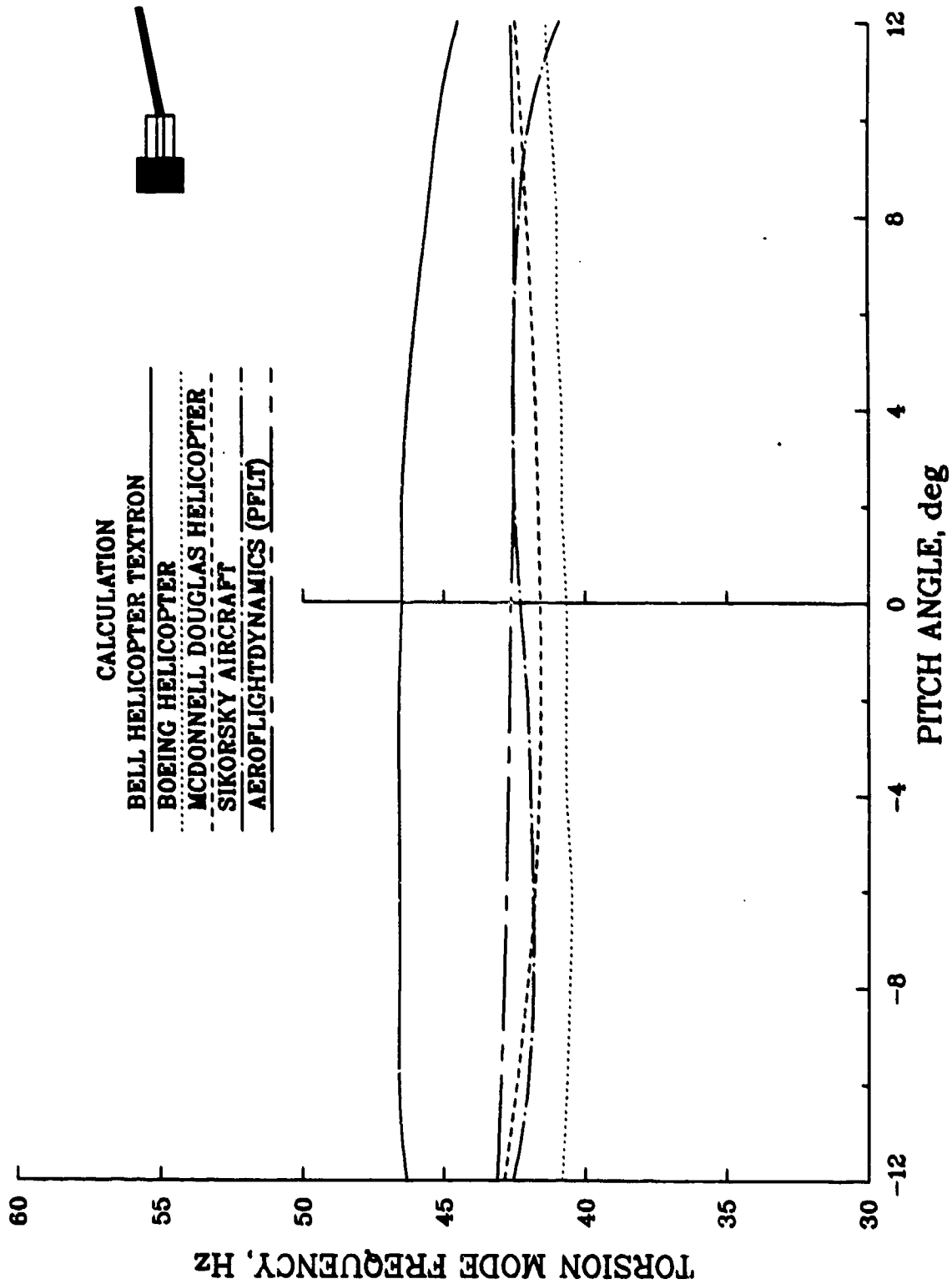
AEROFLIGHTDYNAMICS (PFLT)



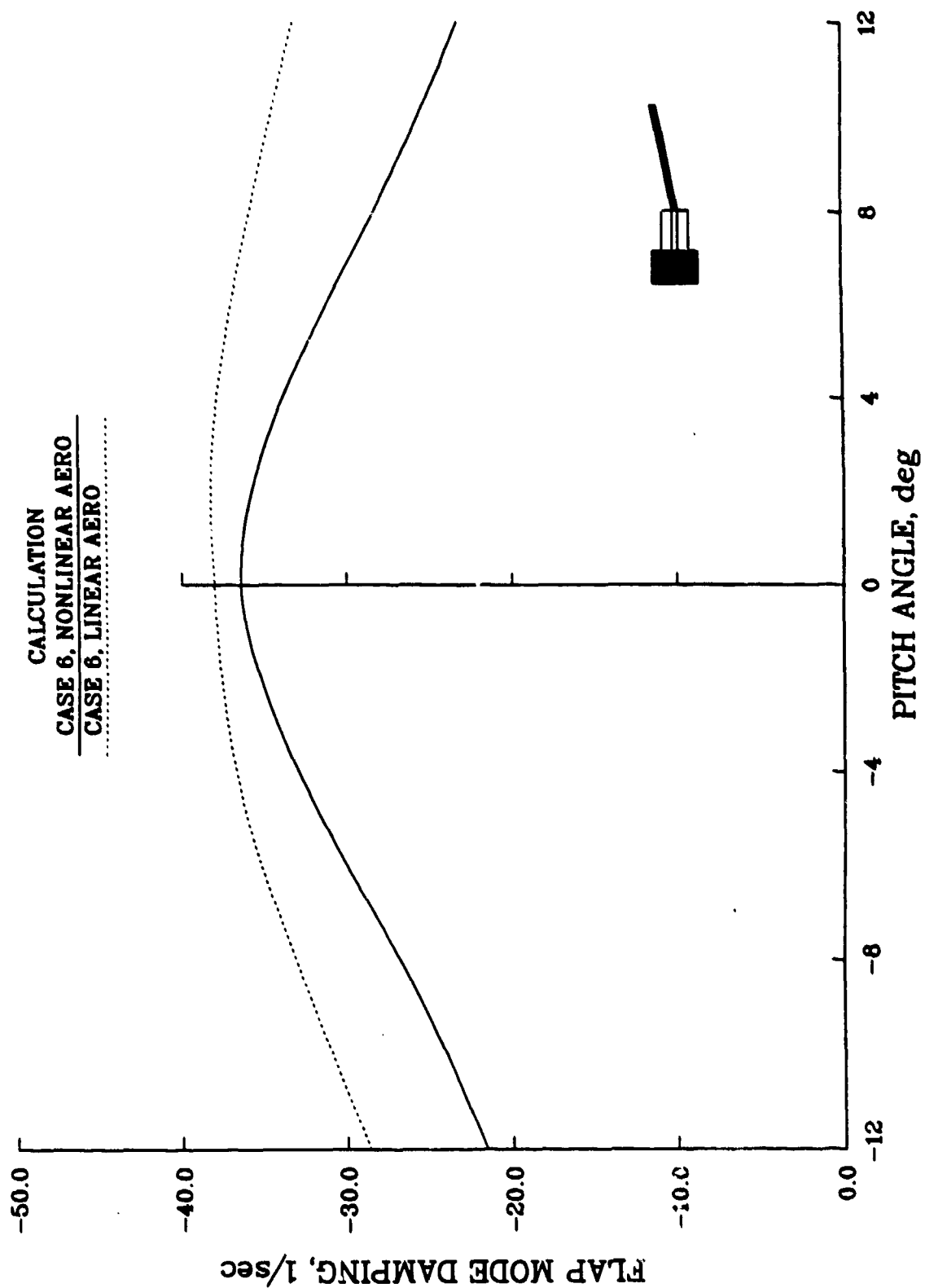
**TORSION MODE DAMPING - TASK 86g**  
**LINEAR AERODYNAMIC COEFFICIENTS**  
**CASE 6 - TORSIONALLY SOFT ROTOR**



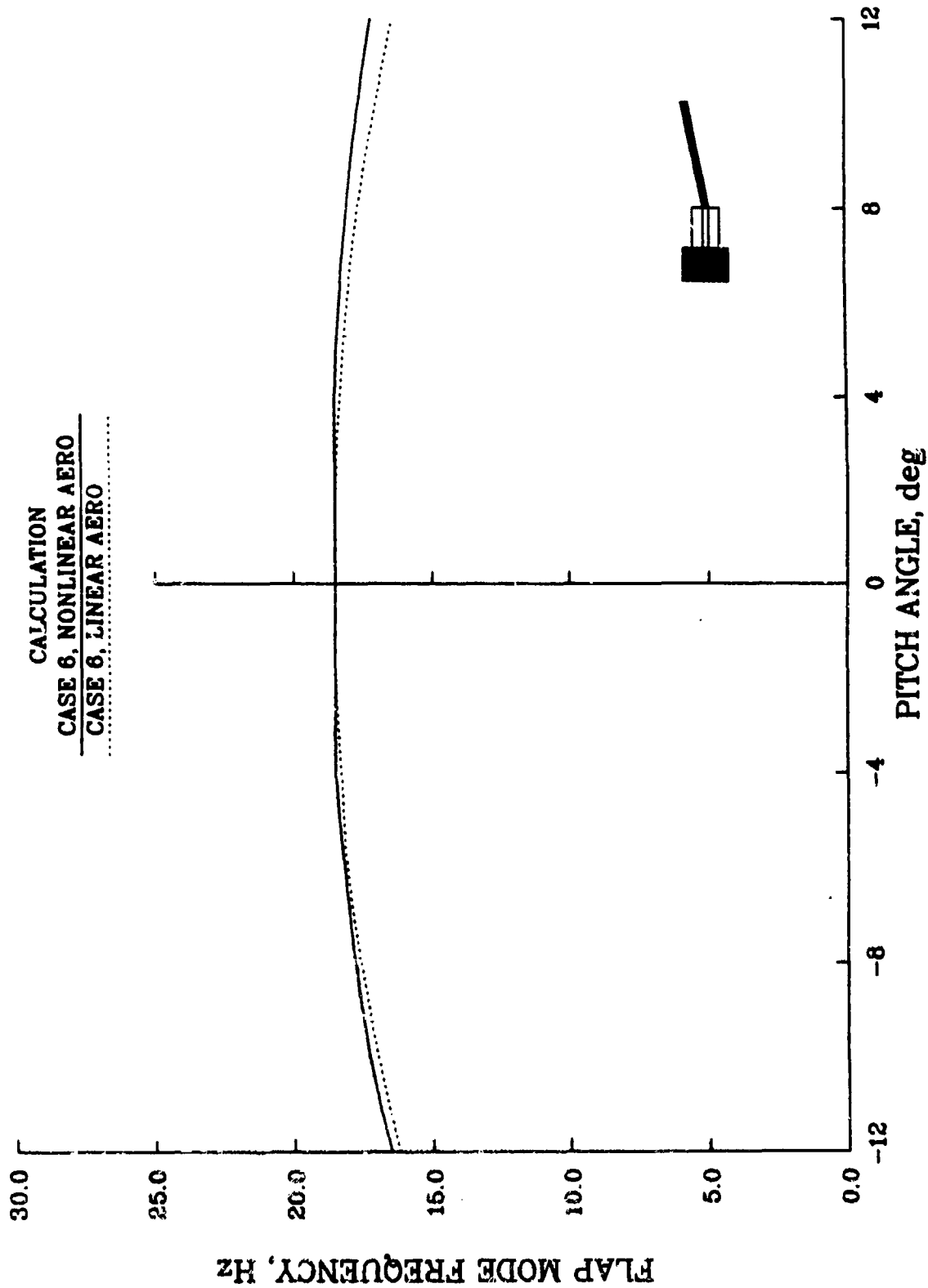
**TORSION MODE FREQUENCY - TASK 86g**  
**LINEAR AERODYNAMIC COEFFICIENTS**  
**CASE 6 - TORSIONALLY SOFT ROTOR**



# FLAP MODE DAMPING TORSIONALLY SOFT ROTOR BELL HELICOPTER TEXTRON

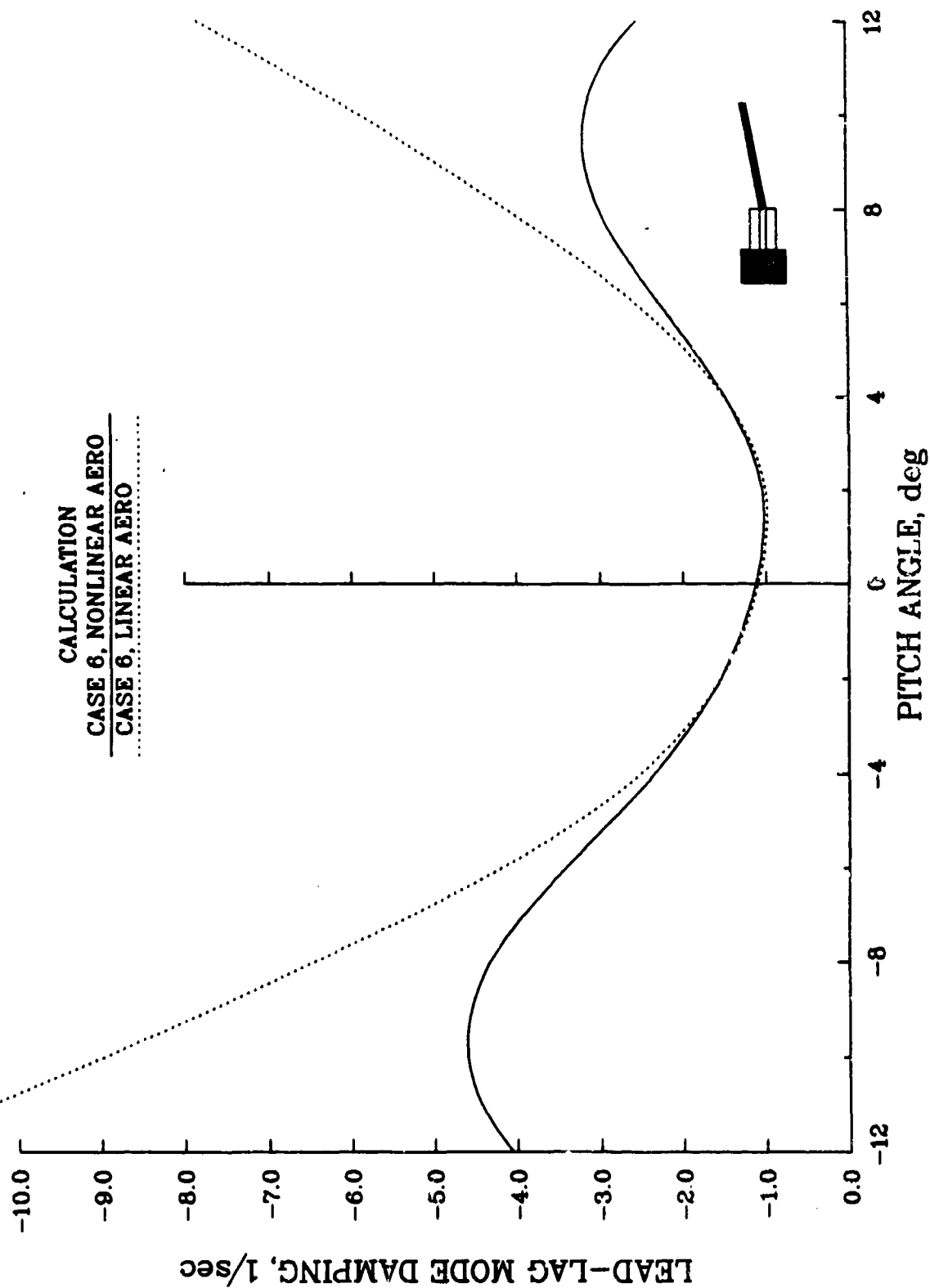


FLAP MODE FREQUENCY  
TORSIONALLY SOFT ROTOR  
BELL HELICOPTER TEXTRON



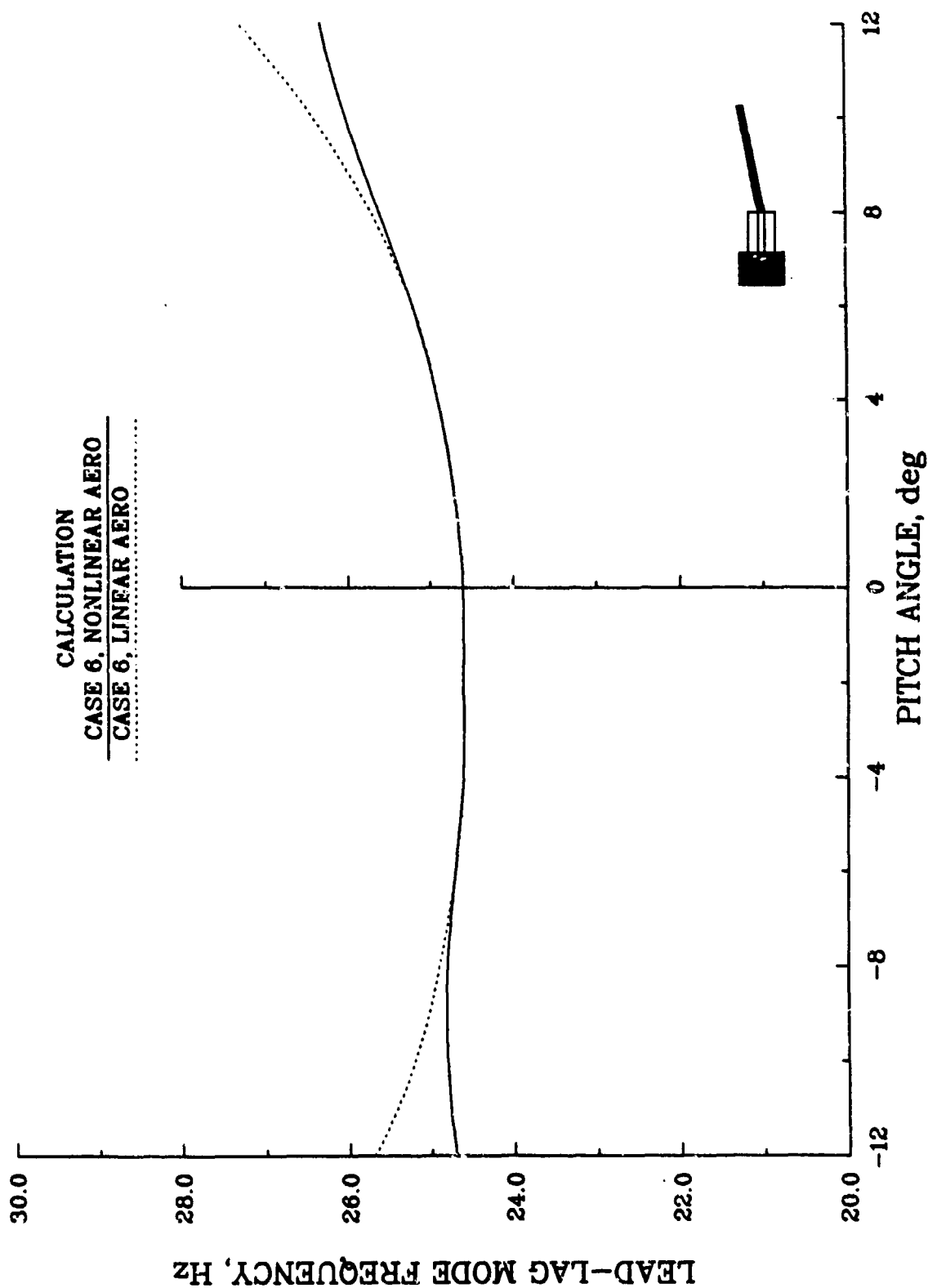
LEAD-LAG MODE DAMPING  
TORSIONALLY SOFT ROTOR  
BELL HELICOPTER TEXTRON

CALCULATION  
CASE 6, NONLINEAR AERO  
CASE 6, LINEAR AERO

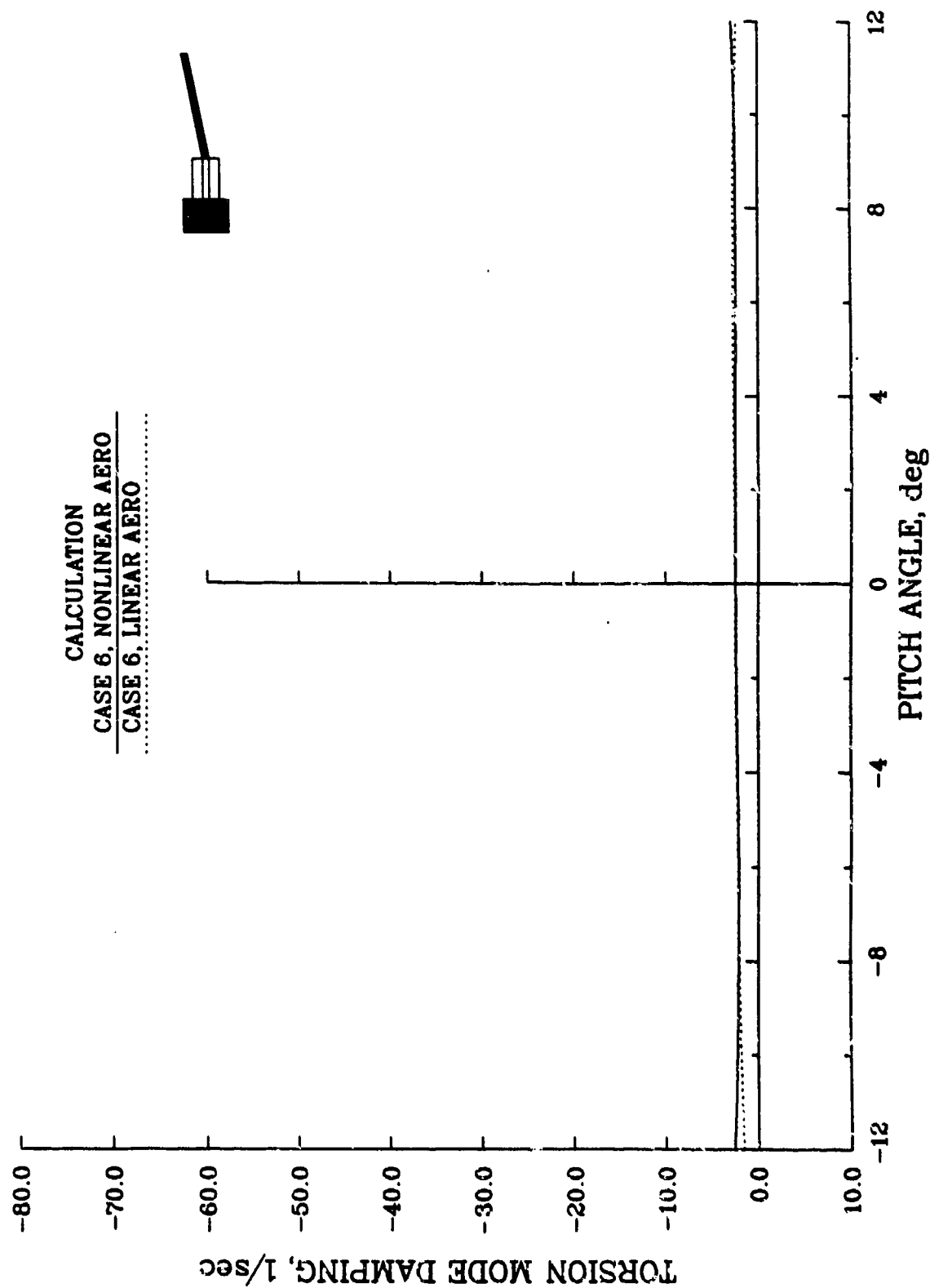




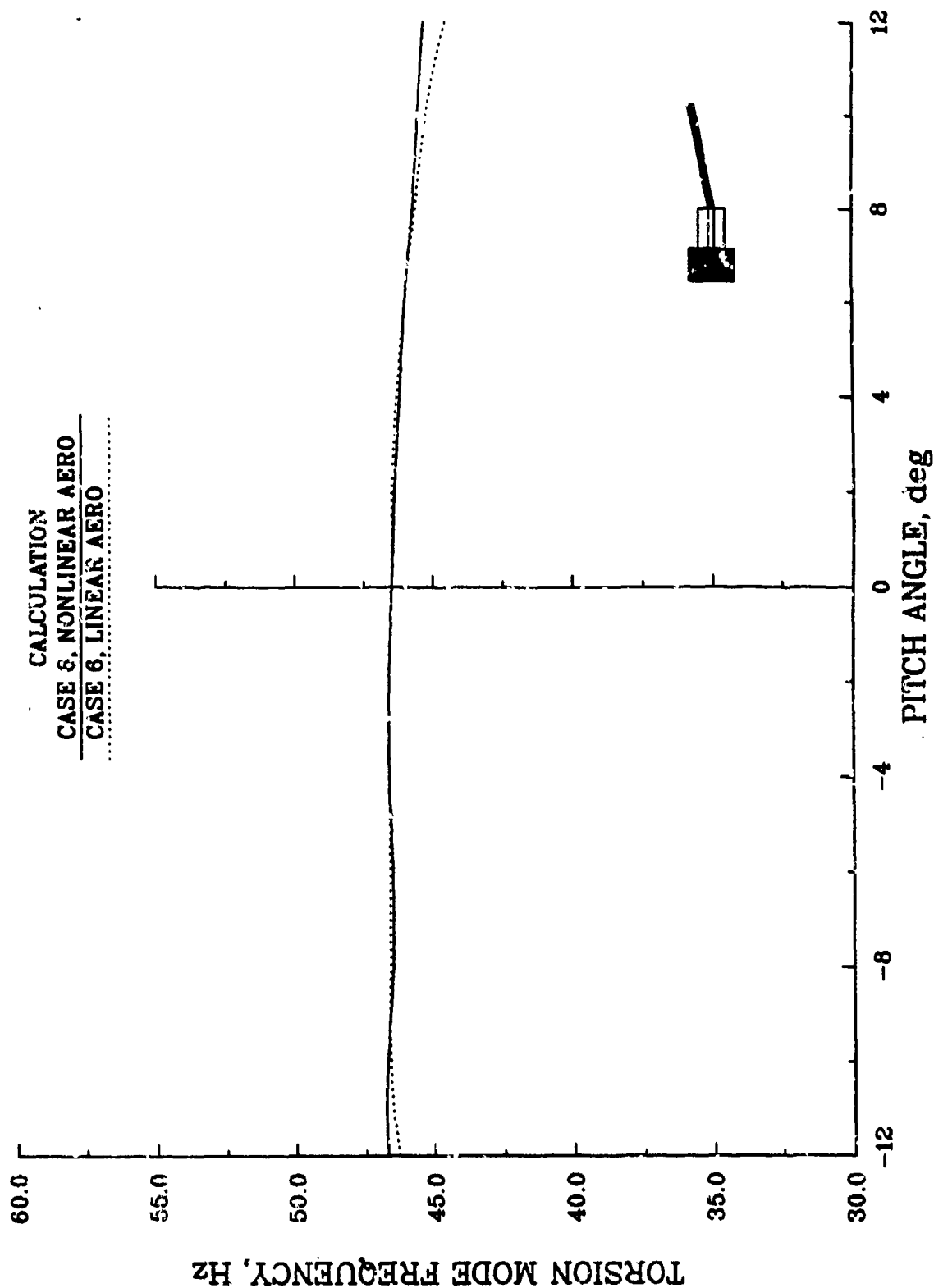
# LEAD-LAG MODE FREQUENCY TORSIONALLY SOFT ROTOR BELL HELICOPTER TEXTRON



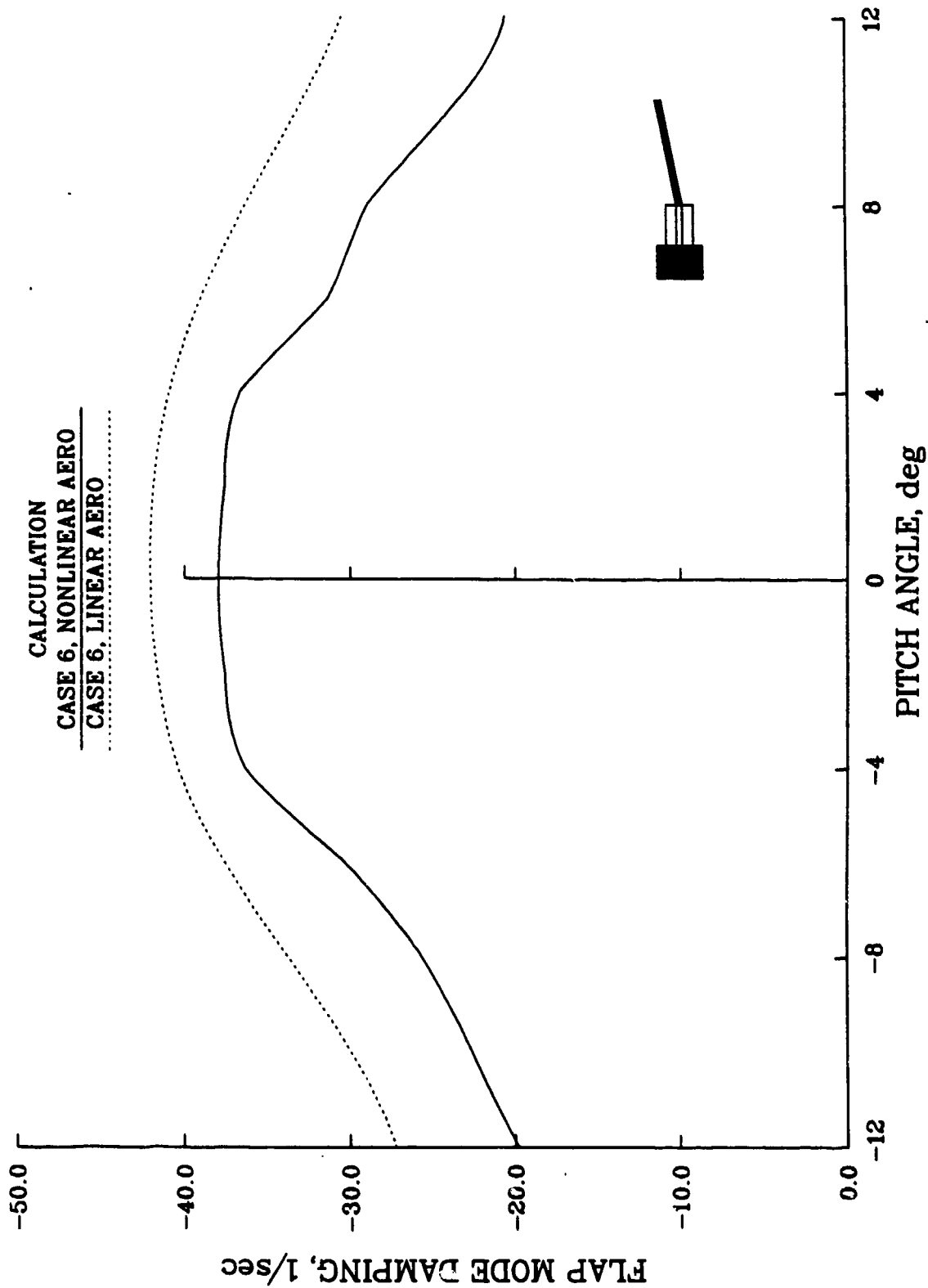
# TORSION MODE DAMPING TORSIONALLY SOFT ROTOR BELL HELICOPTER TEXTRON



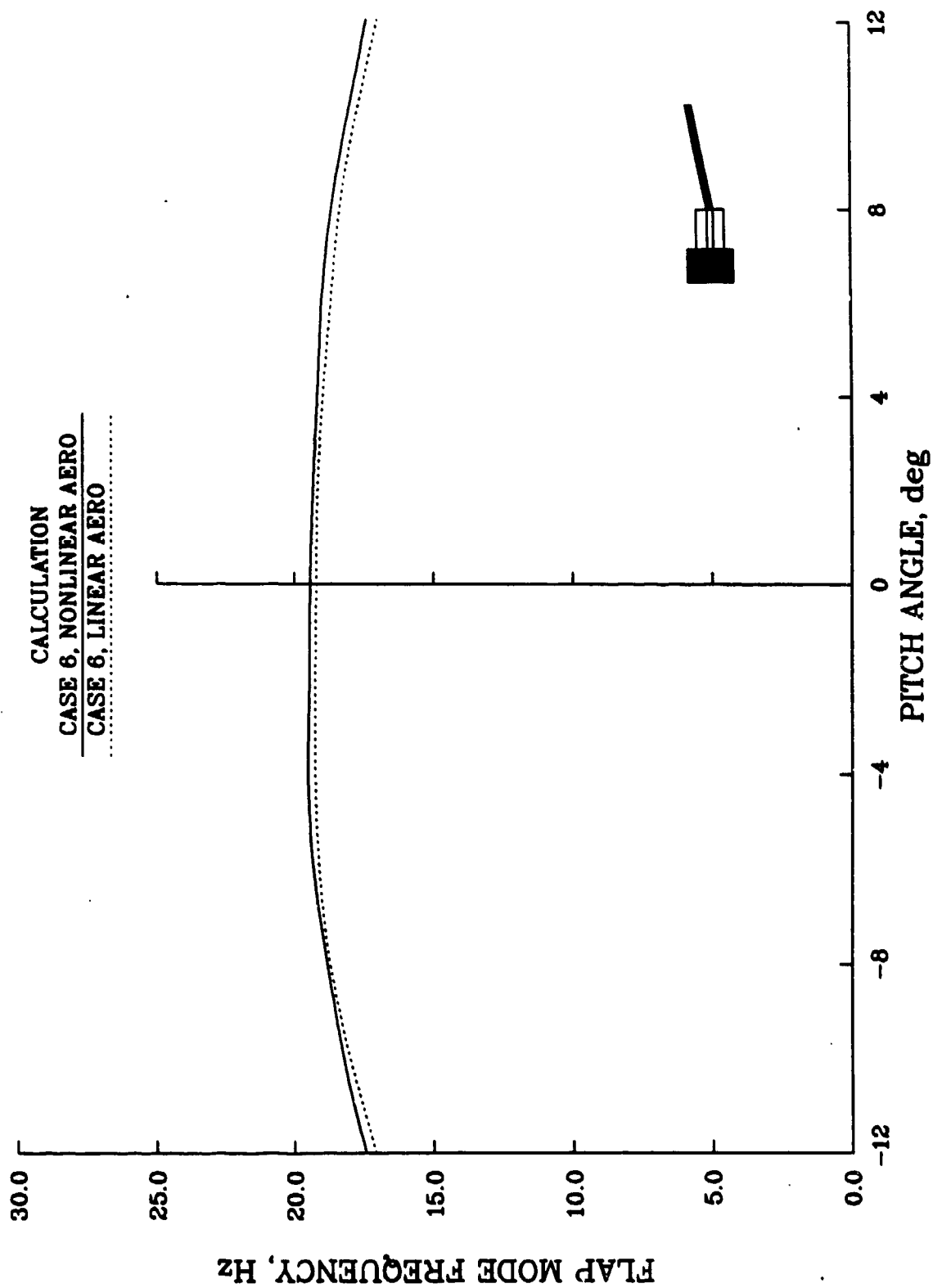
TORSION MODE FREQUENCY  
TORSIONALLY SOFT ROTOR  
BELL HELICOPTER TEXTRON



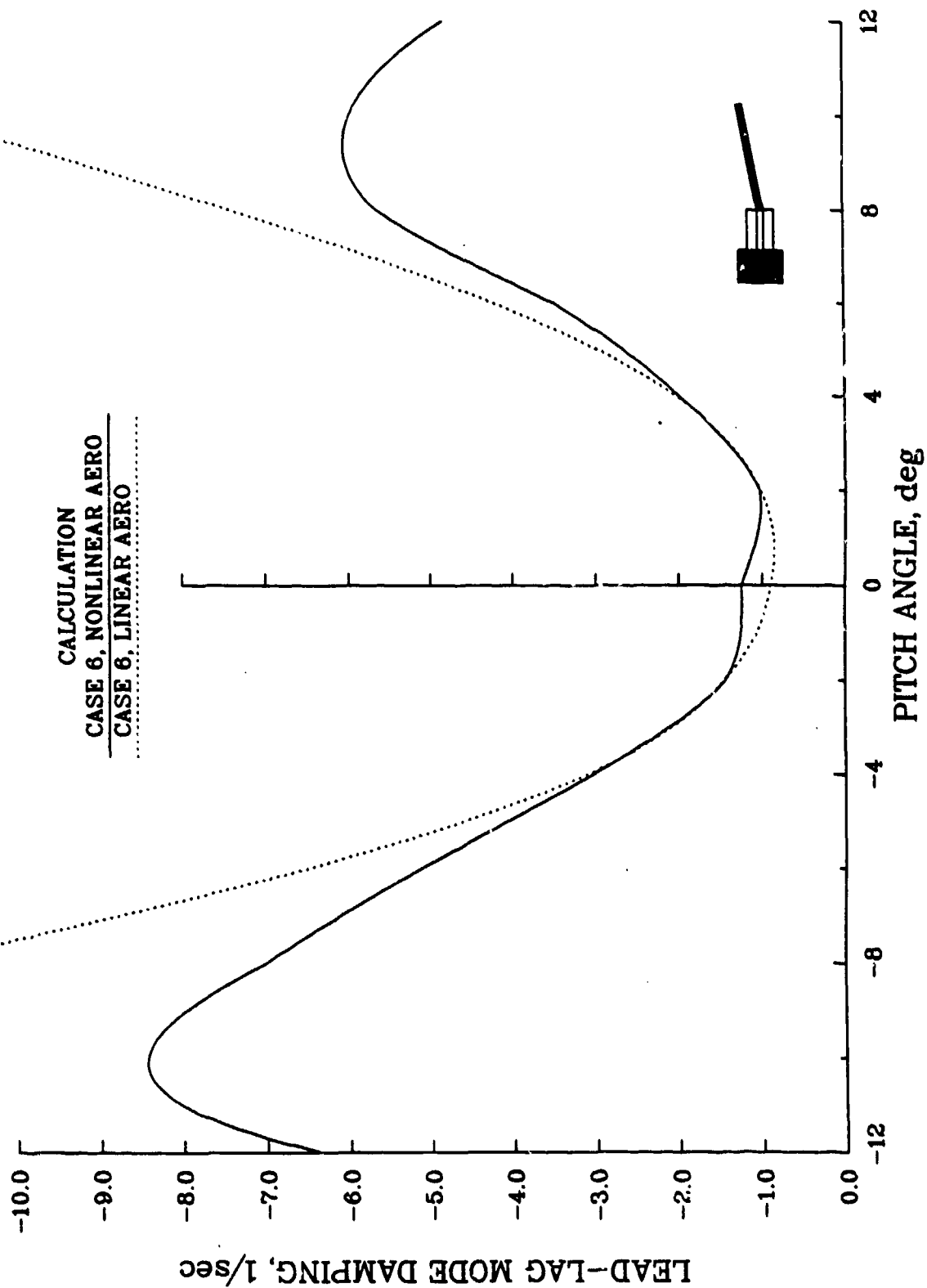
FLAP MODE DAMPING  
TORSIONALLY SOFT ROTOR  
BOEING HELICOPTER



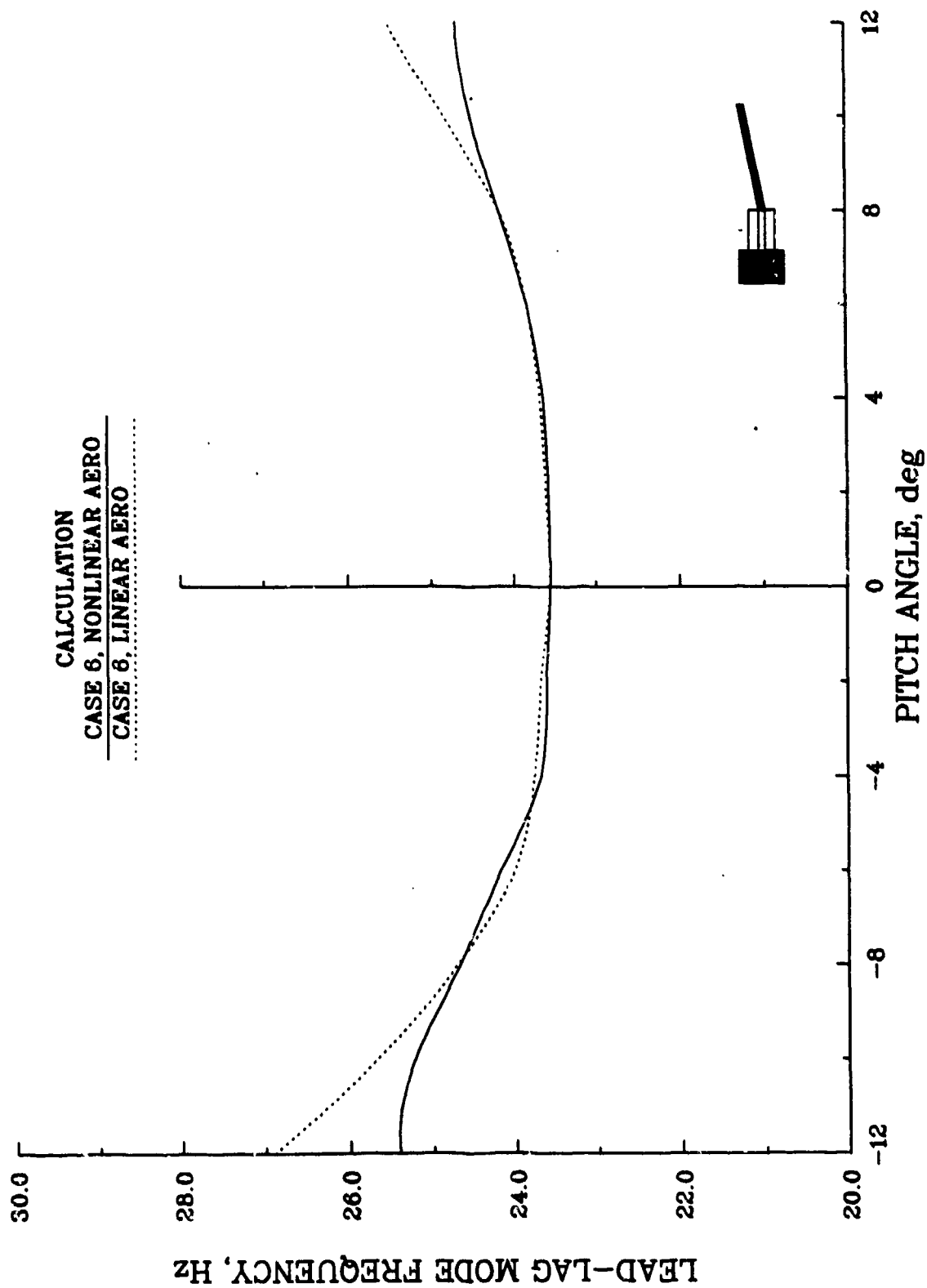
# FLAP MODE FREQUENCY TORSIONALLY SOFT ROTOR BOEING HELICOPTER



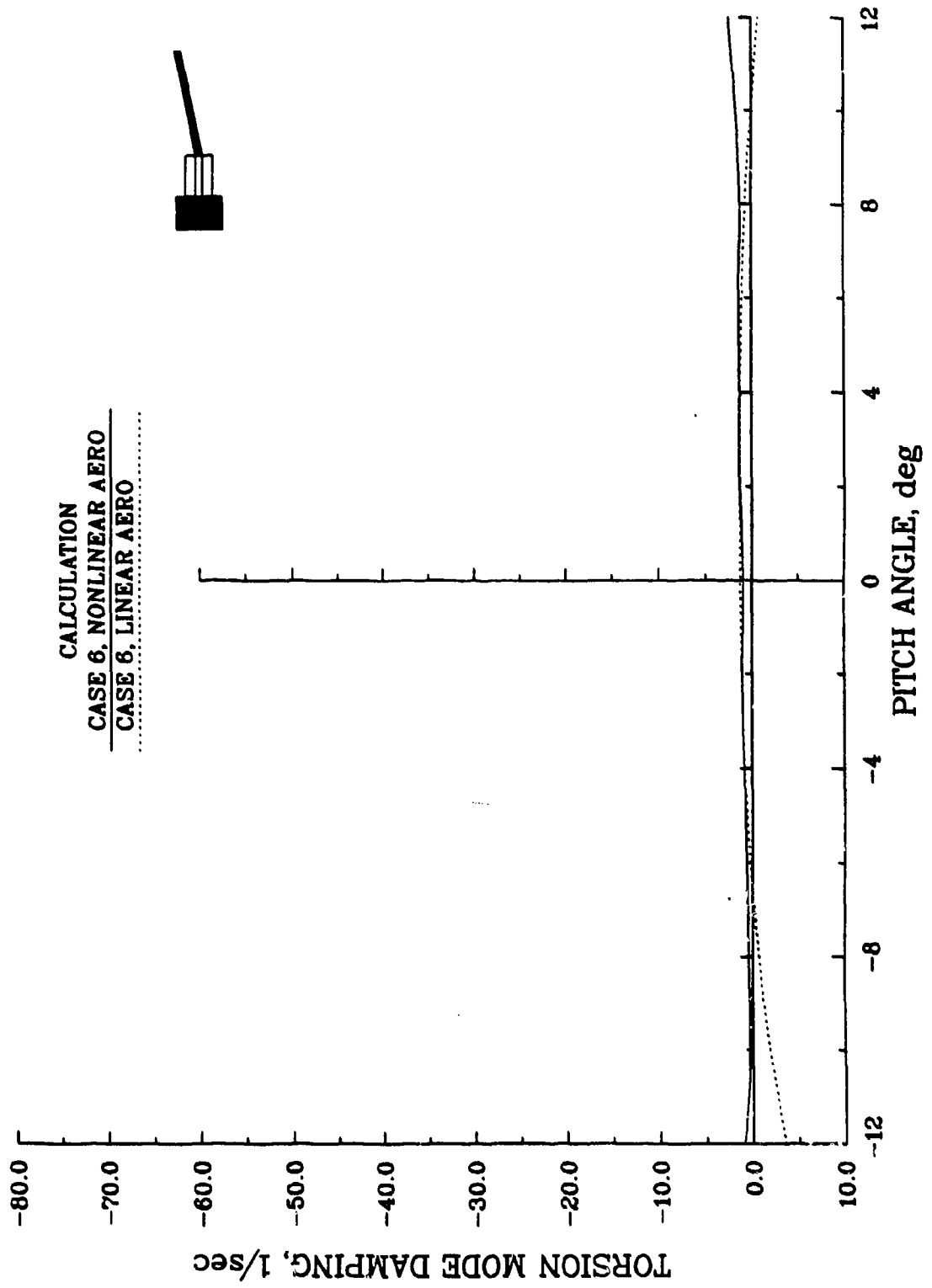
# LEAD-LAG MODE DAMPING TORSIONALLY SOFT ROTOR BOEING HELICOPTER



**CALCULATION**  
**CASE 6, NONLINEAR AERO**  
**CASE 6, LINEAR AERO**

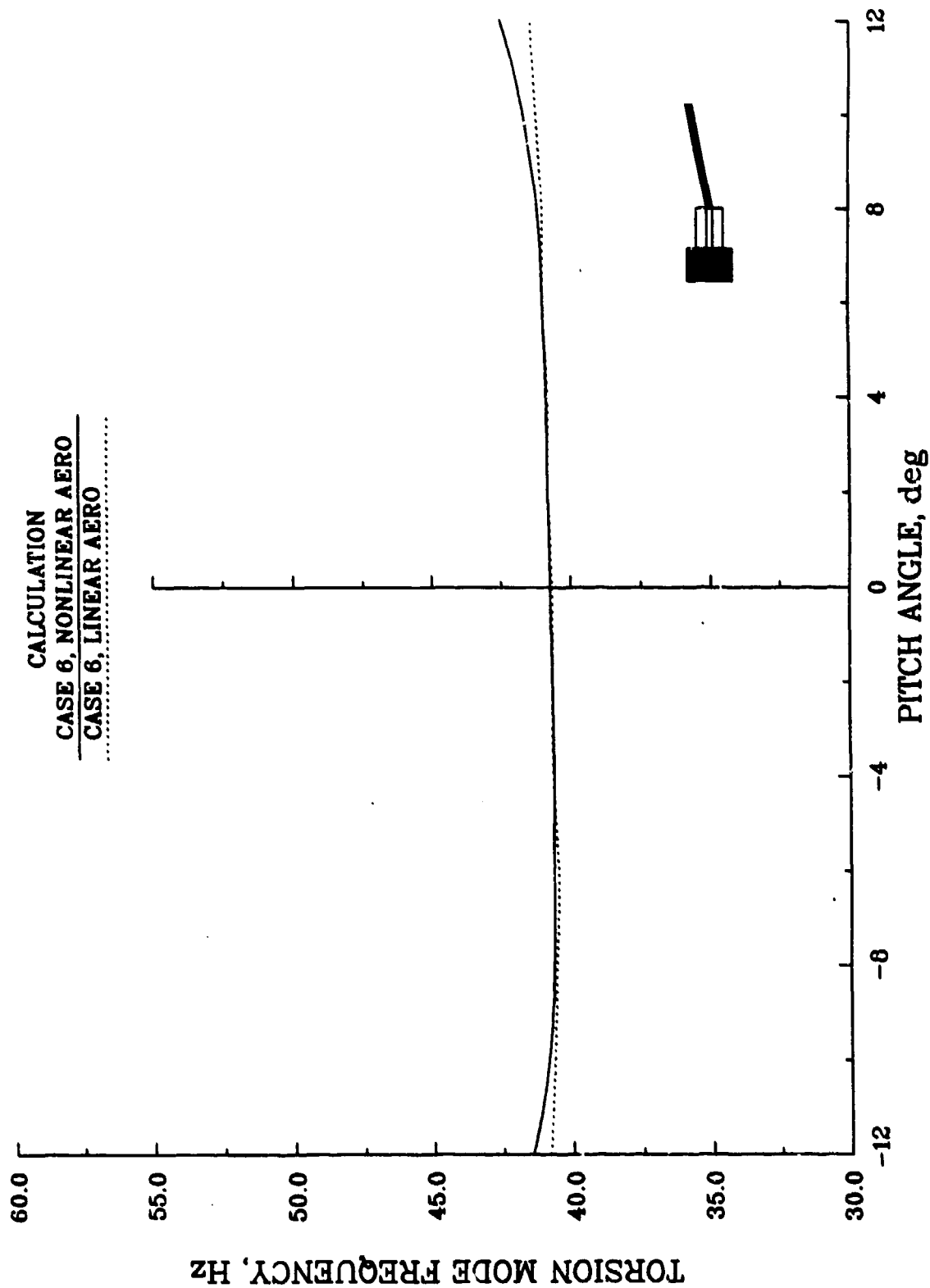


# TORSION MODE DAMPING TORSIONALLY SOFT ROTOR BOEING HELICOPTER

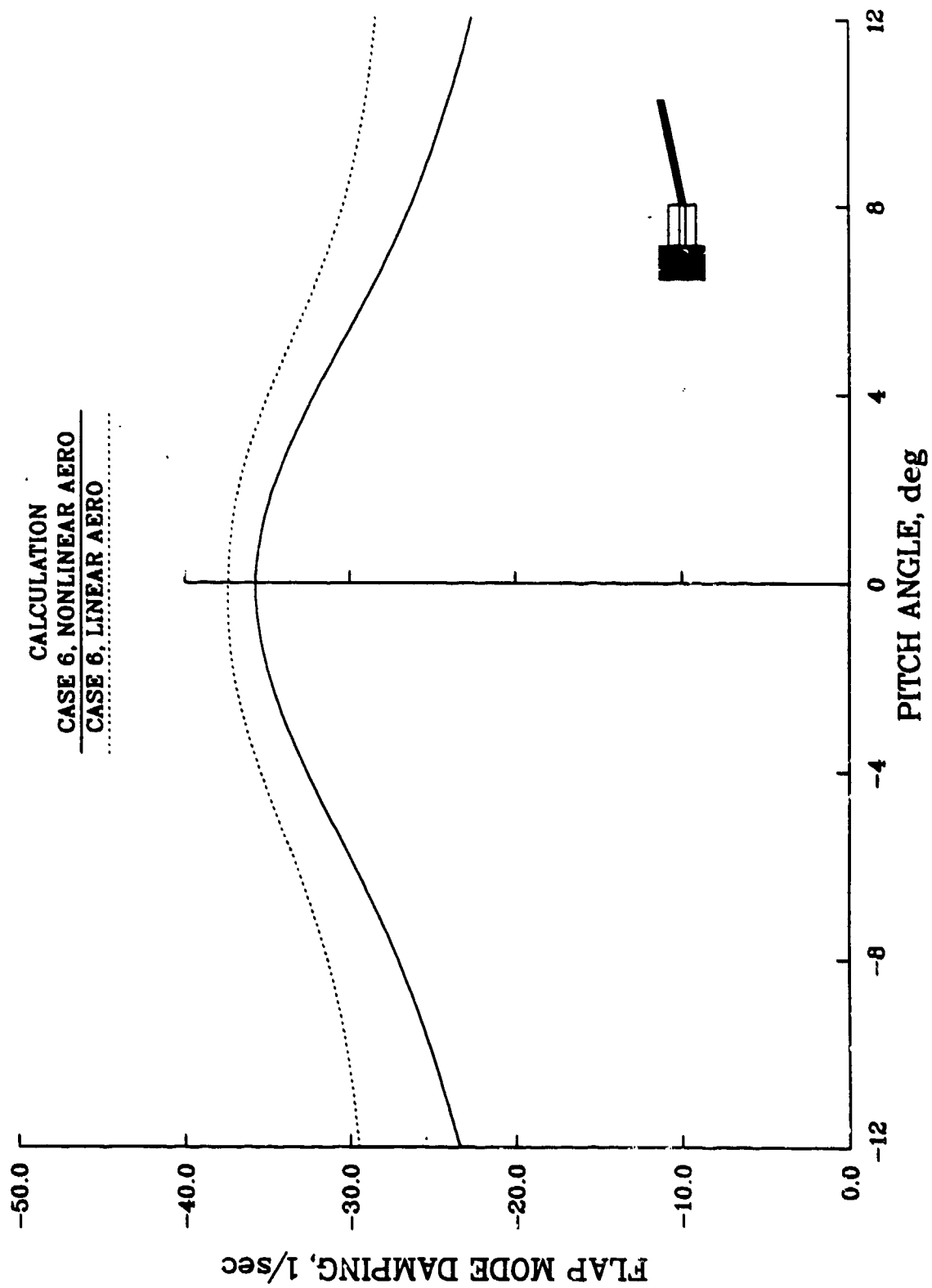




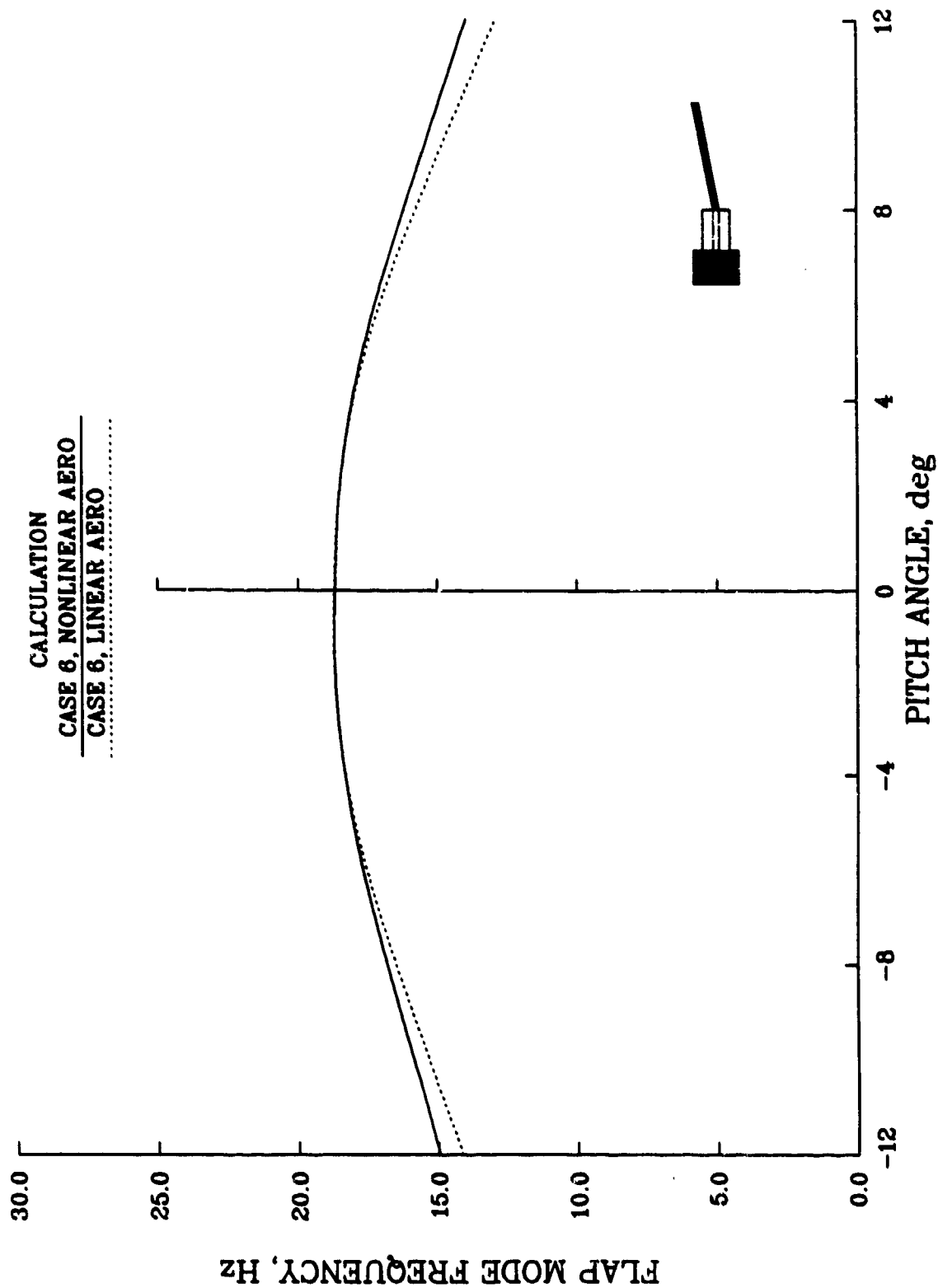
# TORSION MODE FREQUENCY TORSIONALLY SOFT ROTOR BOEING HELICOPTER



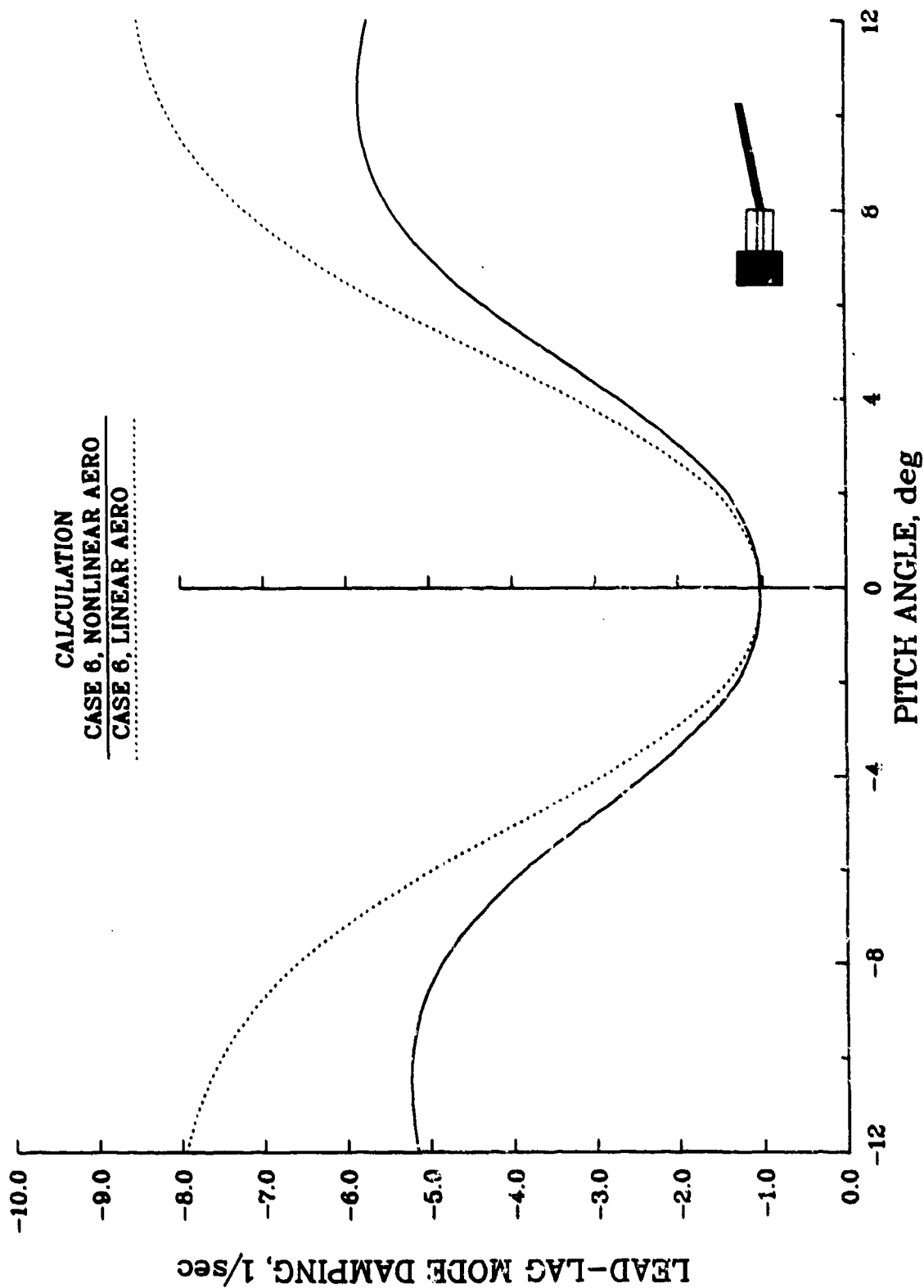
FLAP MODE DAMPING  
TORSIONALLY SOFT ROTOR  
MCDONNELL DOUGLAS HELICOPTER



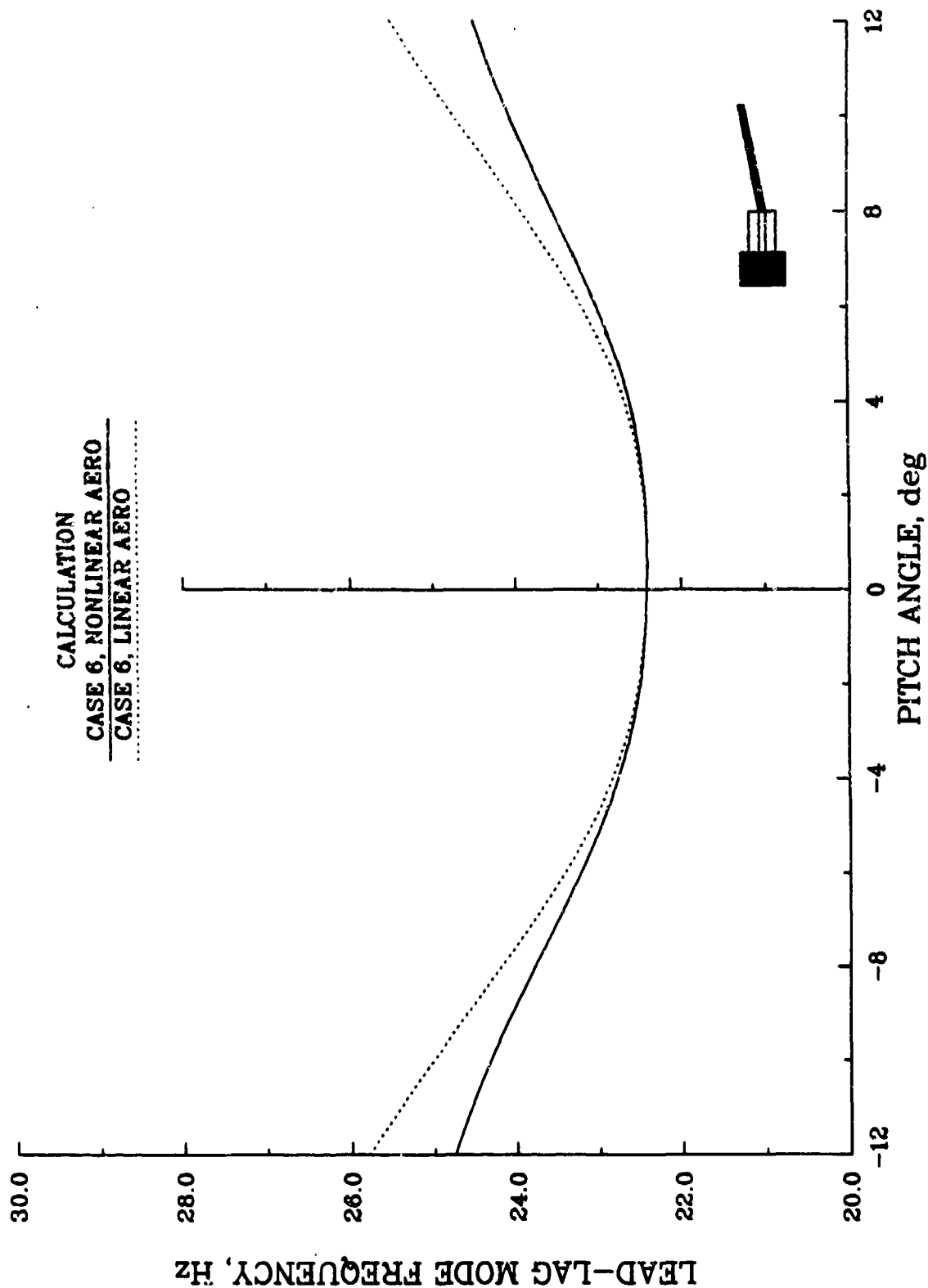
# FLAP MODE FREQUENCY TORSIONALLY SOFT ROTOR MCDONNELL DOUGLAS HELICOPTER



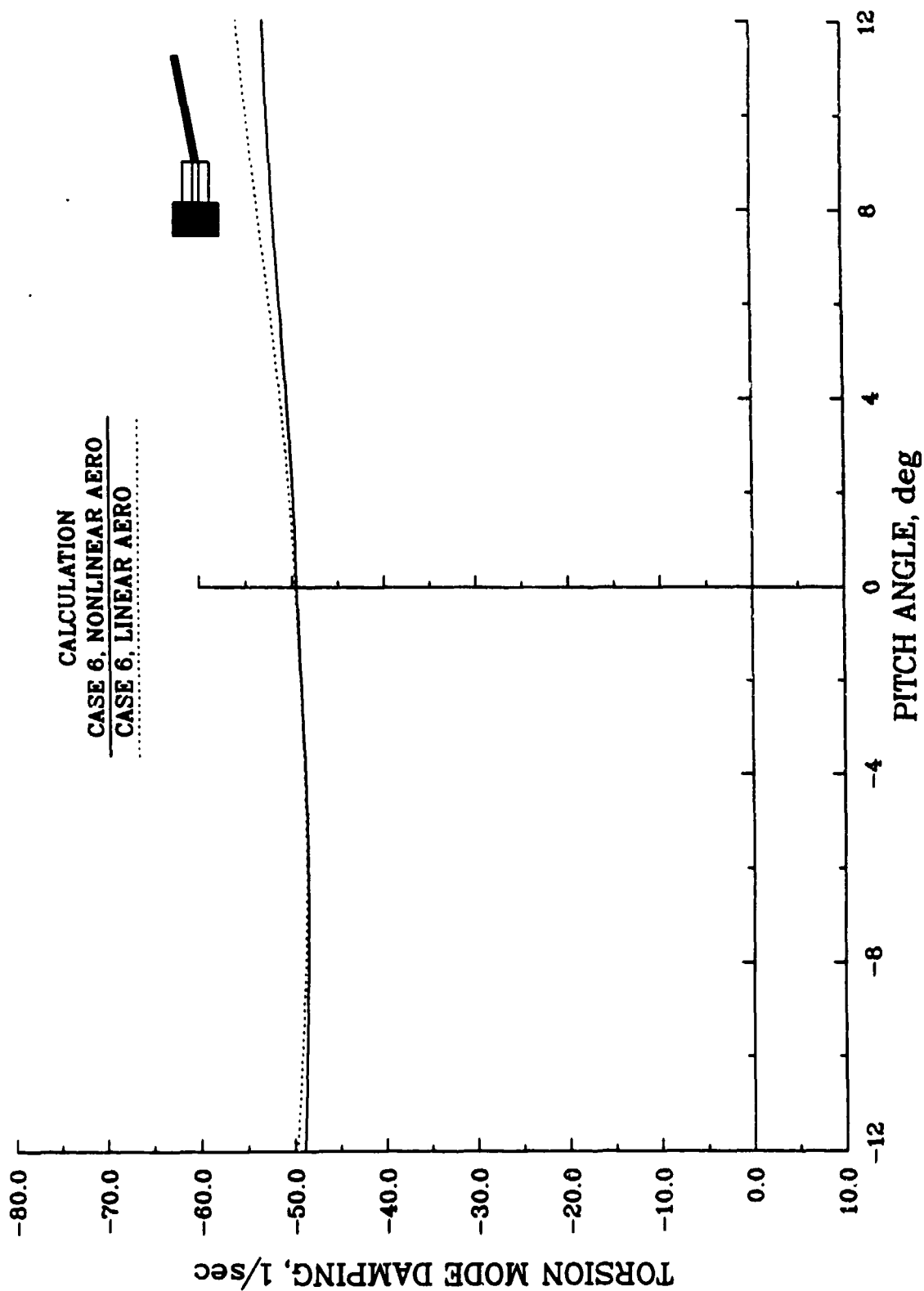
# LEAD-LAG MODE DAMPING TORSIONALLY SOFT ROTOR MCDONNELL DOUGLAS HELICOPTER



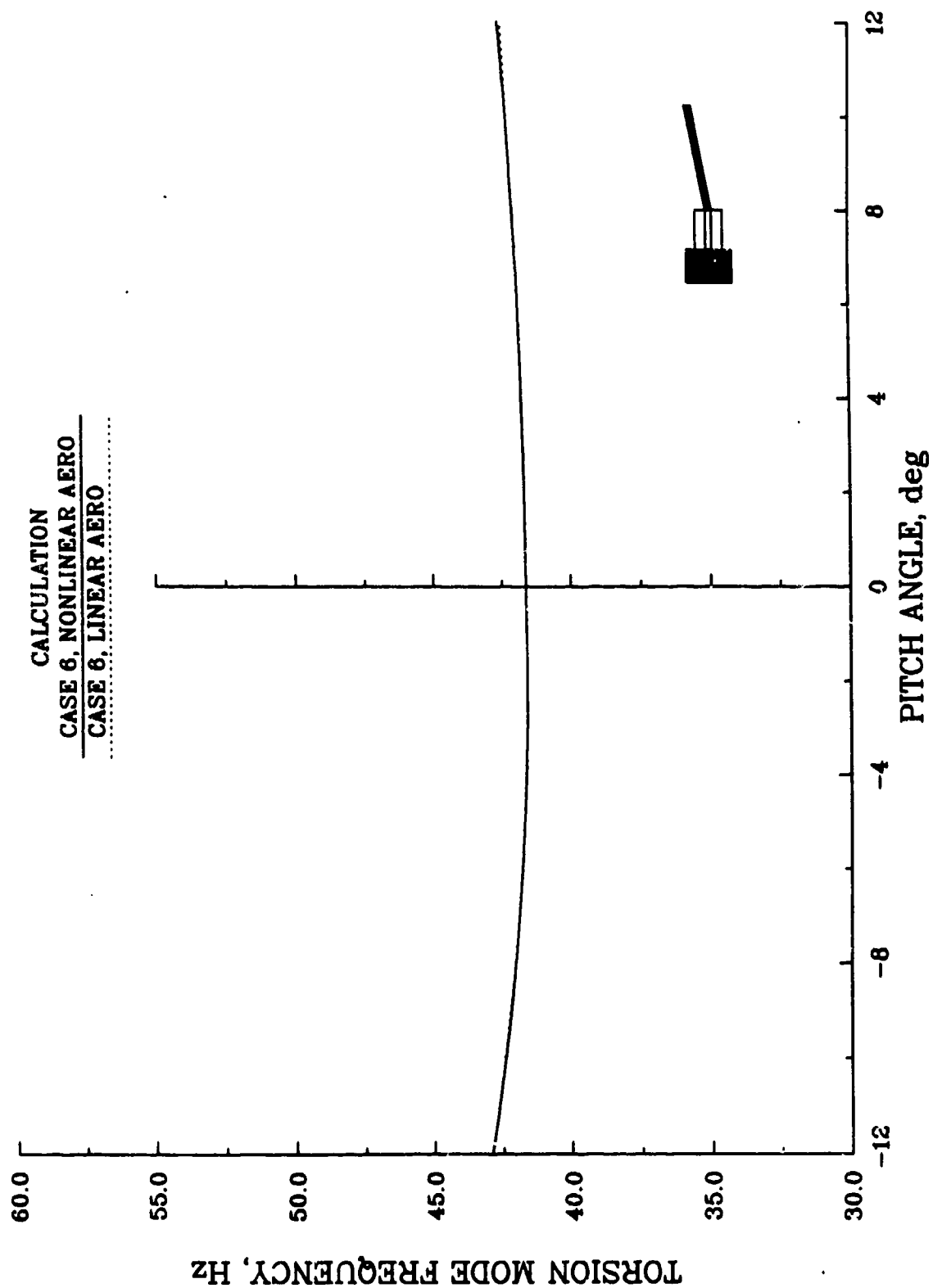
# LEAD-LAG MODE FREQUENCY TORSIONALLY SOFT ROTOR MCDONNELL DOUGLAS HELICOPTER



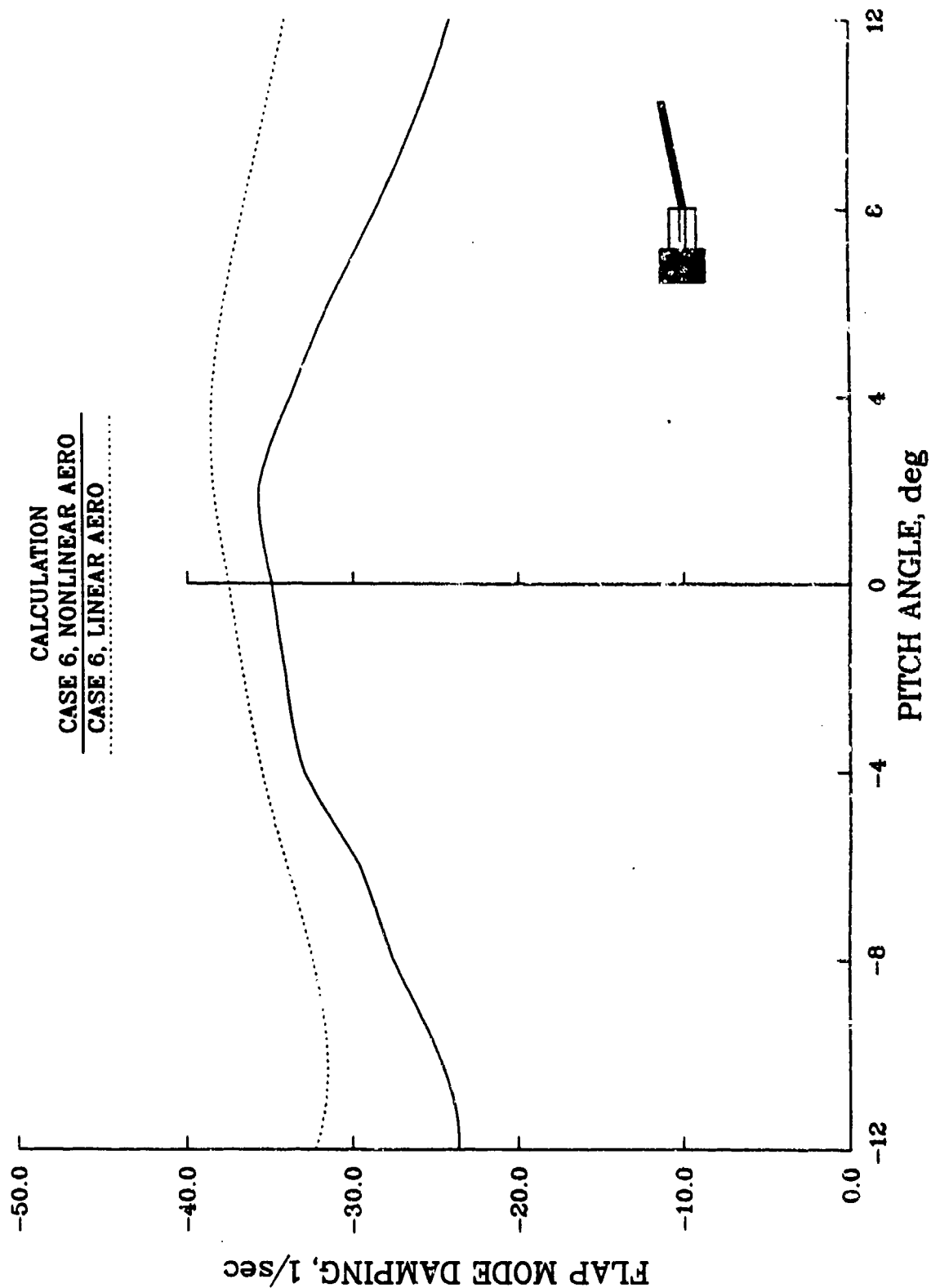
# TORSION MODE DAMPING TORSIONALLY SOFT ROTOR MCDONNELL DOUGLAS HELICOPTER



TORSION MODE FREQUENCY  
TORSIONALLY SOFT ROTOR  
MCDONNELL DOUGLAS HELICOPTER

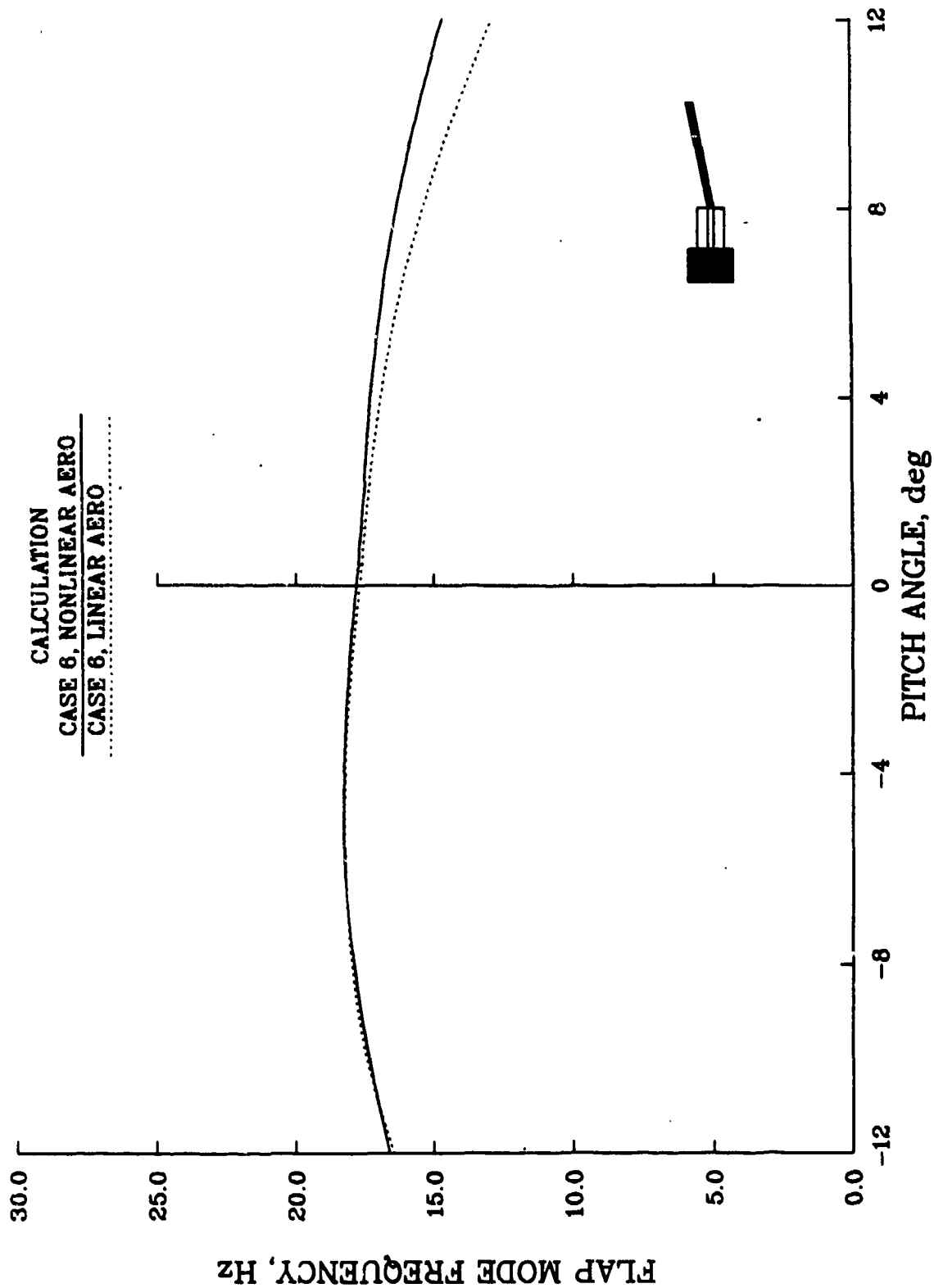


# FLAP MODE DAMPING TORSIONALLY SOFT ROTOR SIKORSKY AIRCRAFT

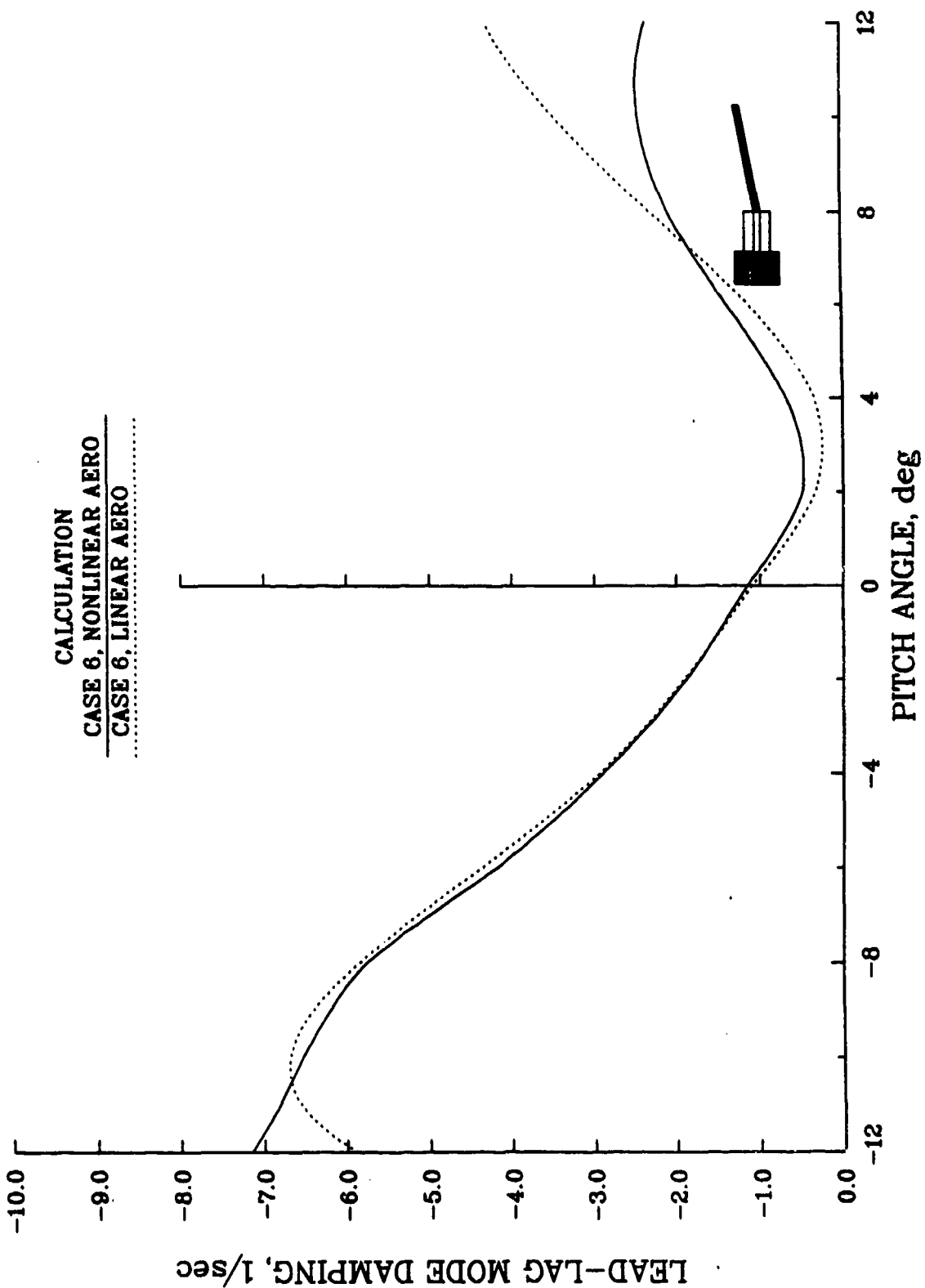




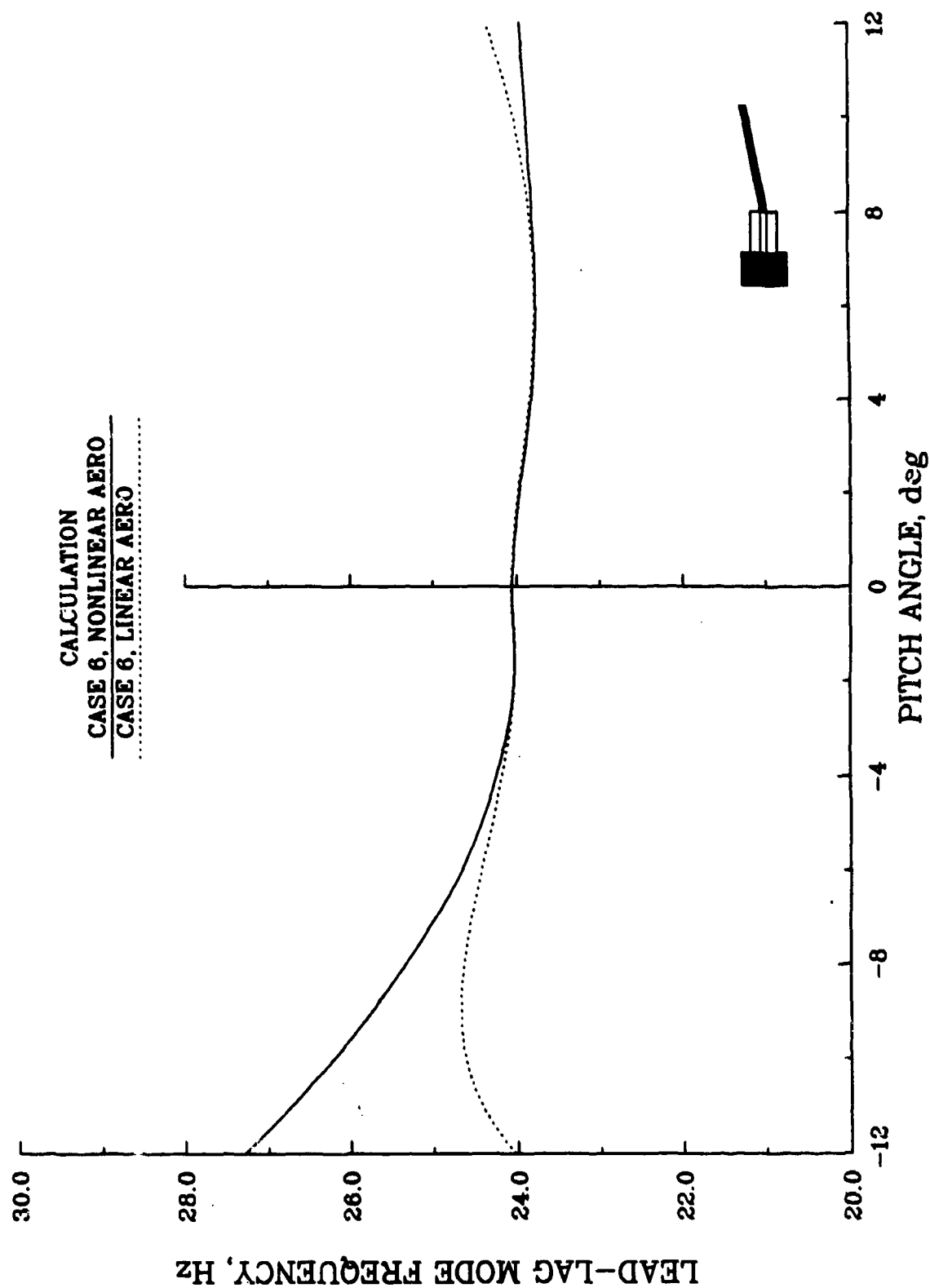
# FLAP MODE FREQUENCY TORSIONALLY SOFT ROTOR SIKORSKY AIRCRAFT



# LEAD-LAG MODE DAMPING TORSIONALLY SOFT ROTOR SIKORSKY AIRCRAFT

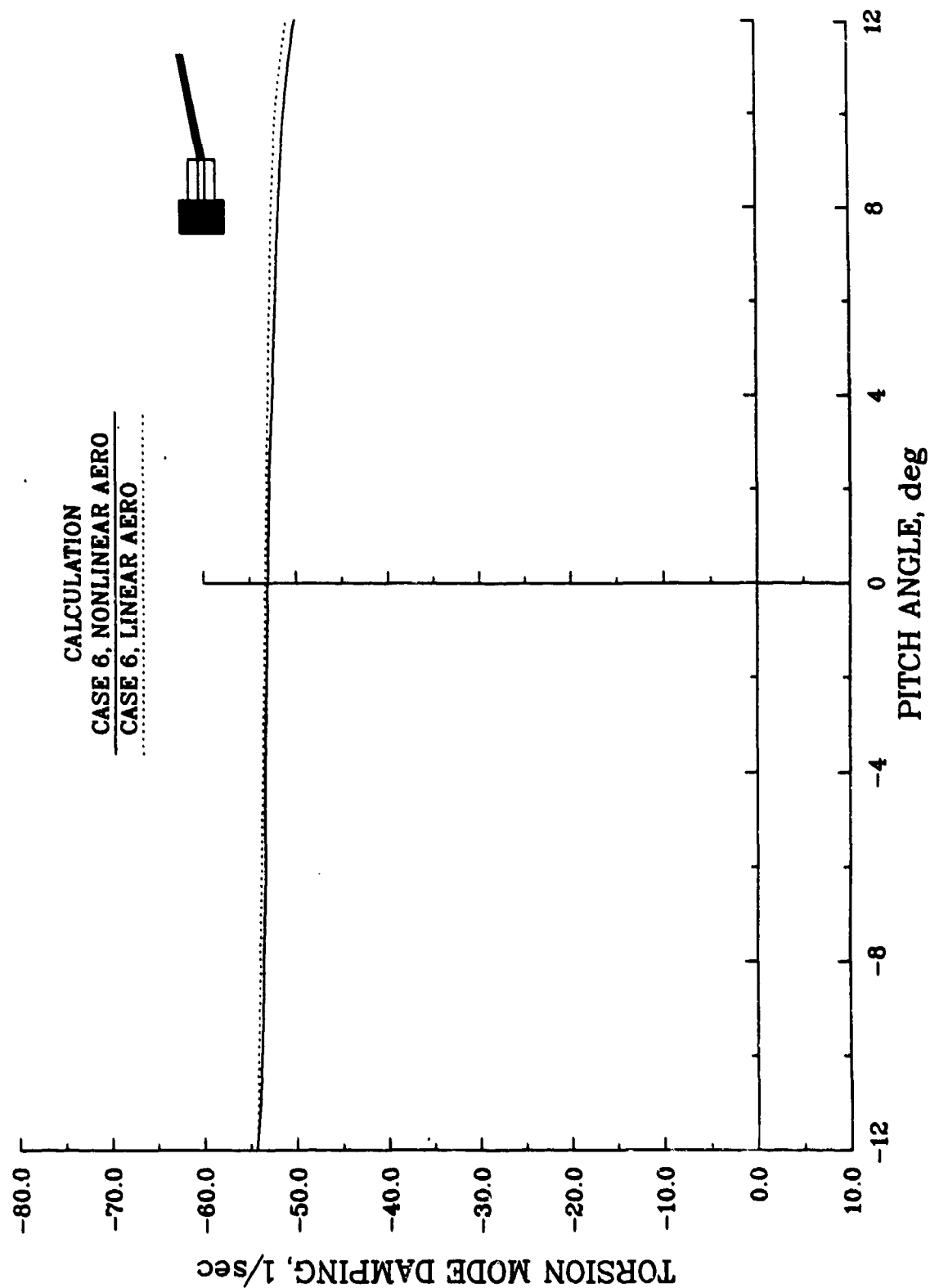


# LEAD-LAG MODE FREQUENCY TORSIONALLY SOFT ROTOR SIKORSKY AIRCRAFT

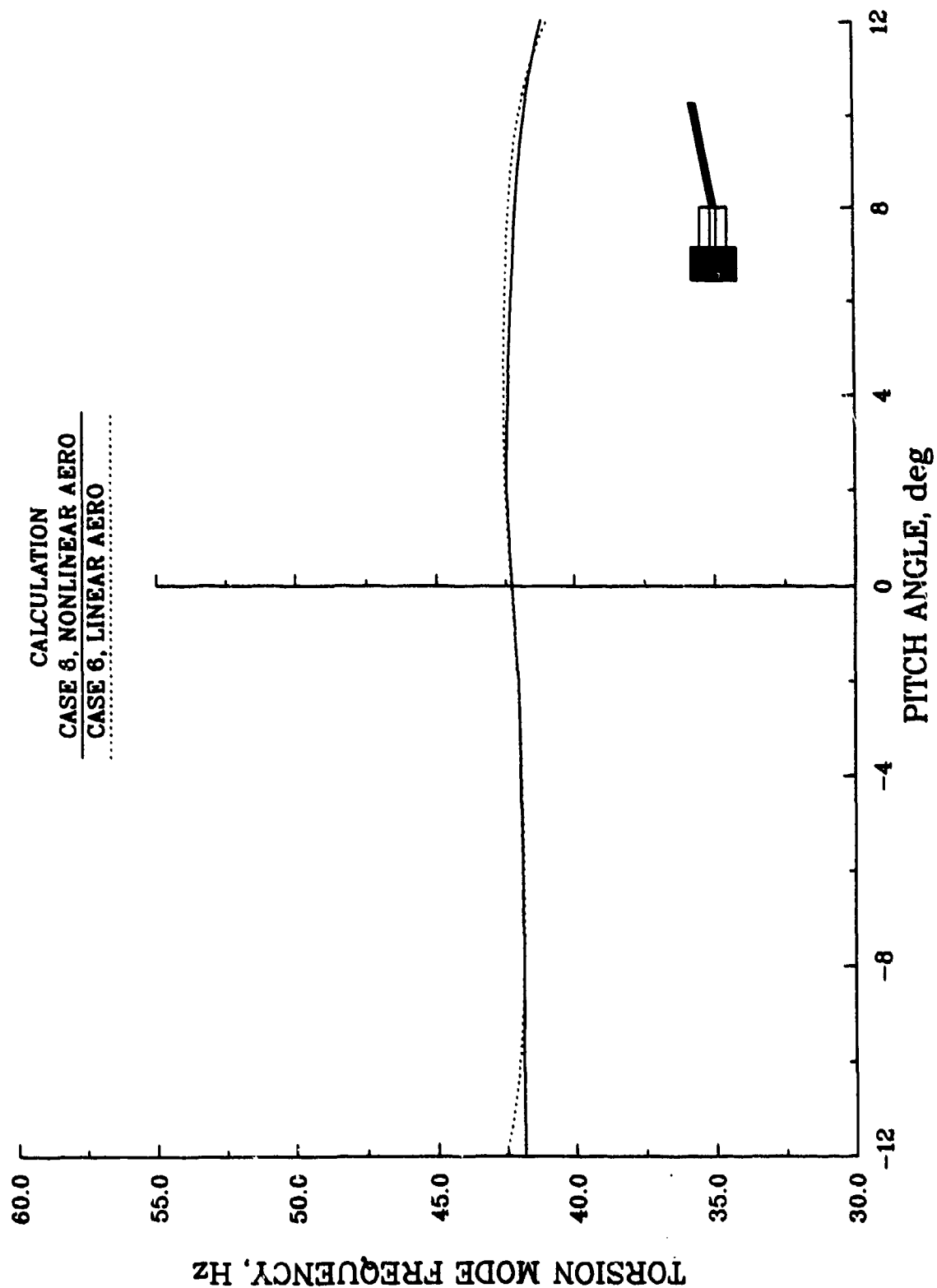


**TORSION MODE DAMPING  
TORSIONALLY SOFT ROTOR  
SIKORSKY AIRCRAFT**

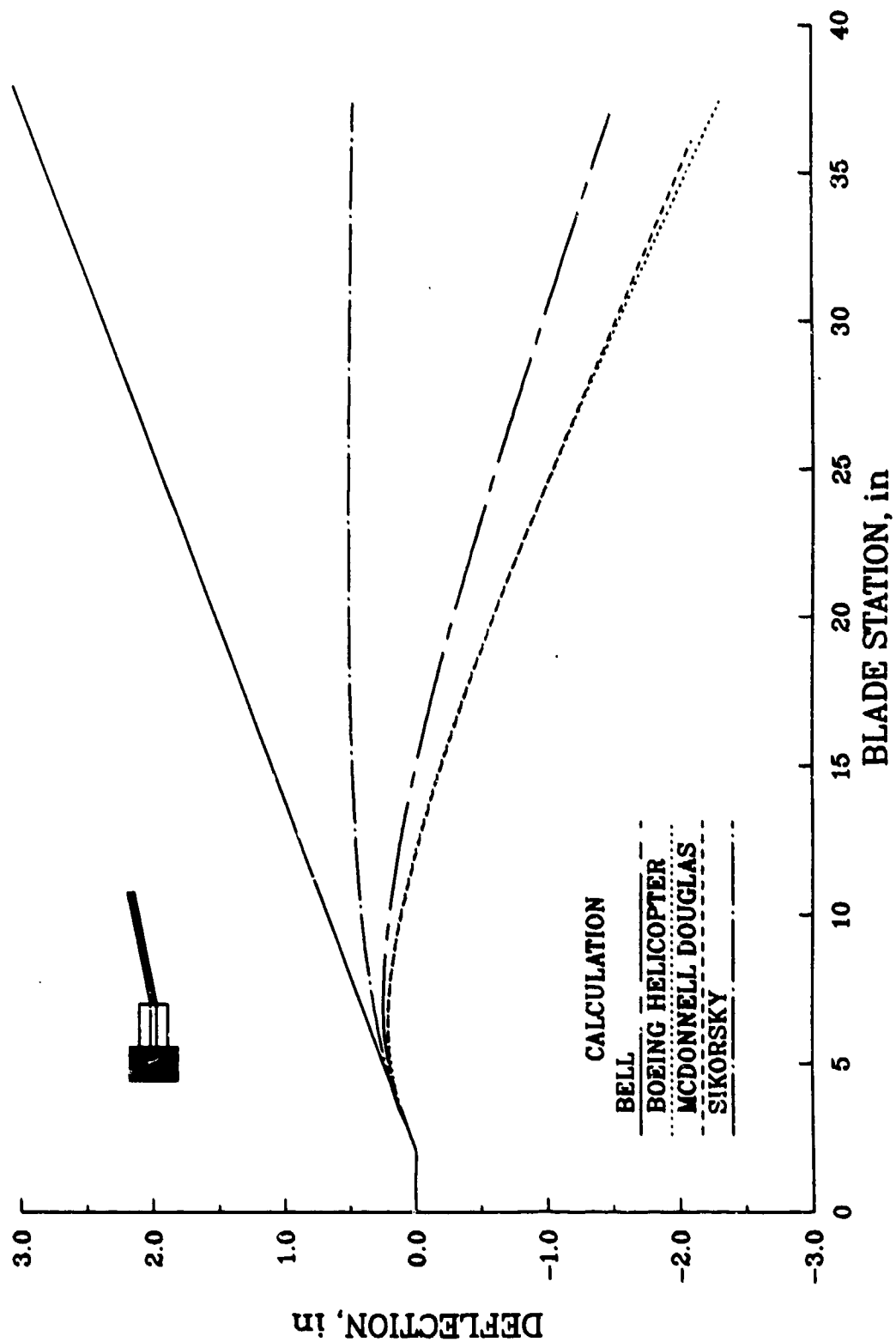
**CALCULATION**  
**CASE 6, NONLINEAR AERO**  
**CASE 6, LINEAR AERO**



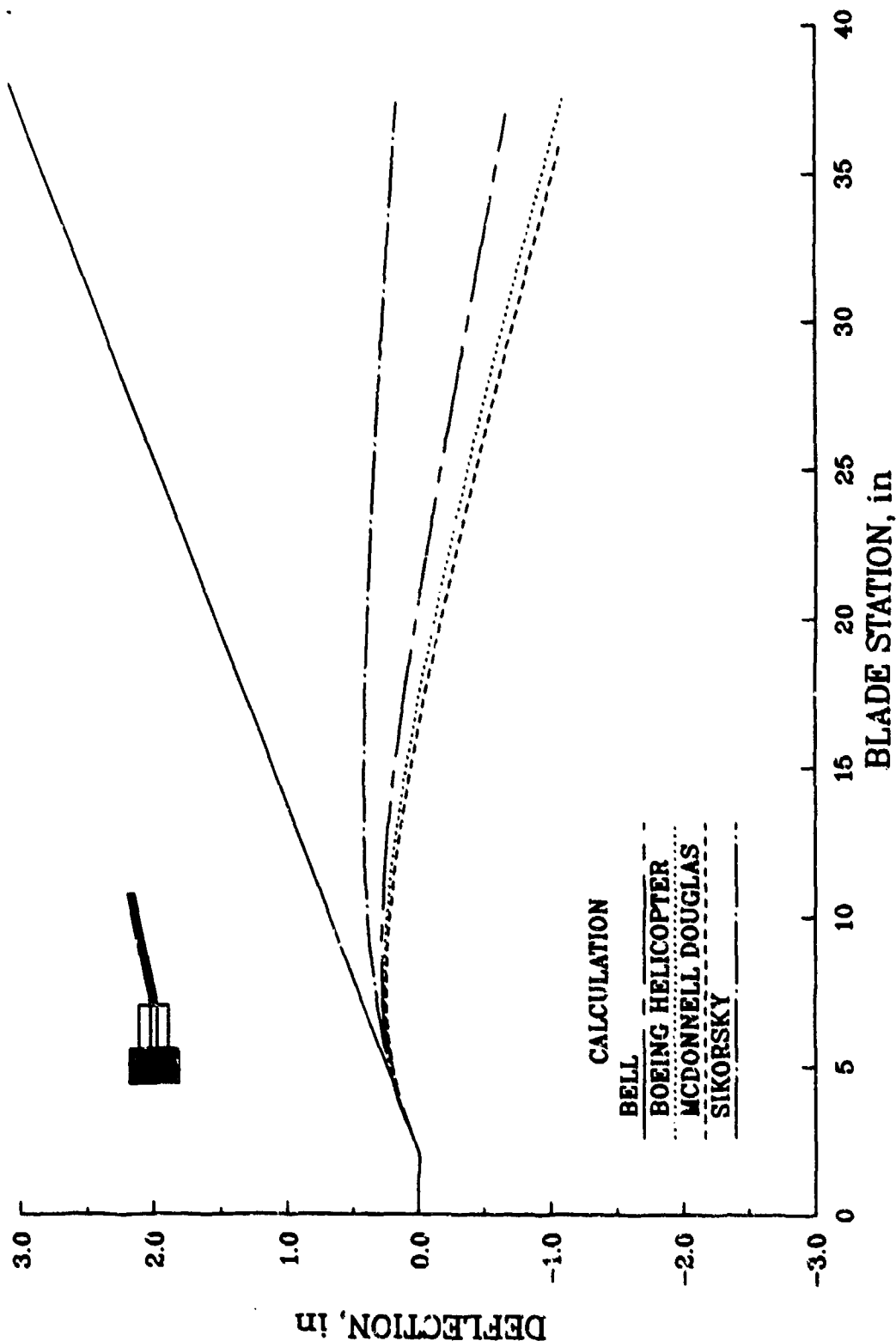
# TORSION MODE FREQUENCY TORSIONALLY SOFT ROTOR SIKORSKY AIRCRAFT



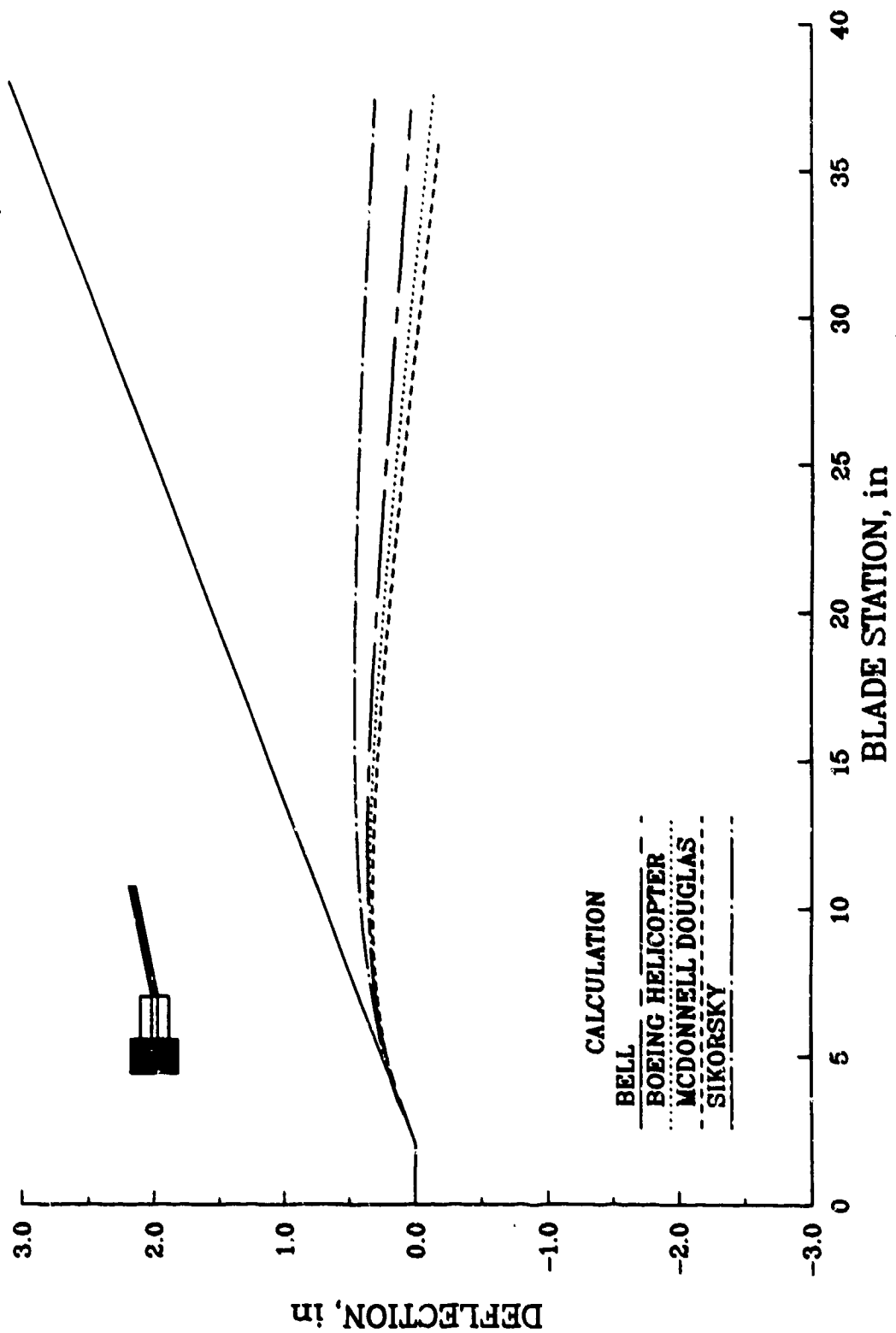
FLAP EQUILIBRIUM DEFLECTION - TASK 86g  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = -12 deg



FLAP EQUILIBRIUM DEFLECTION - TASK 86g  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = -8 deg

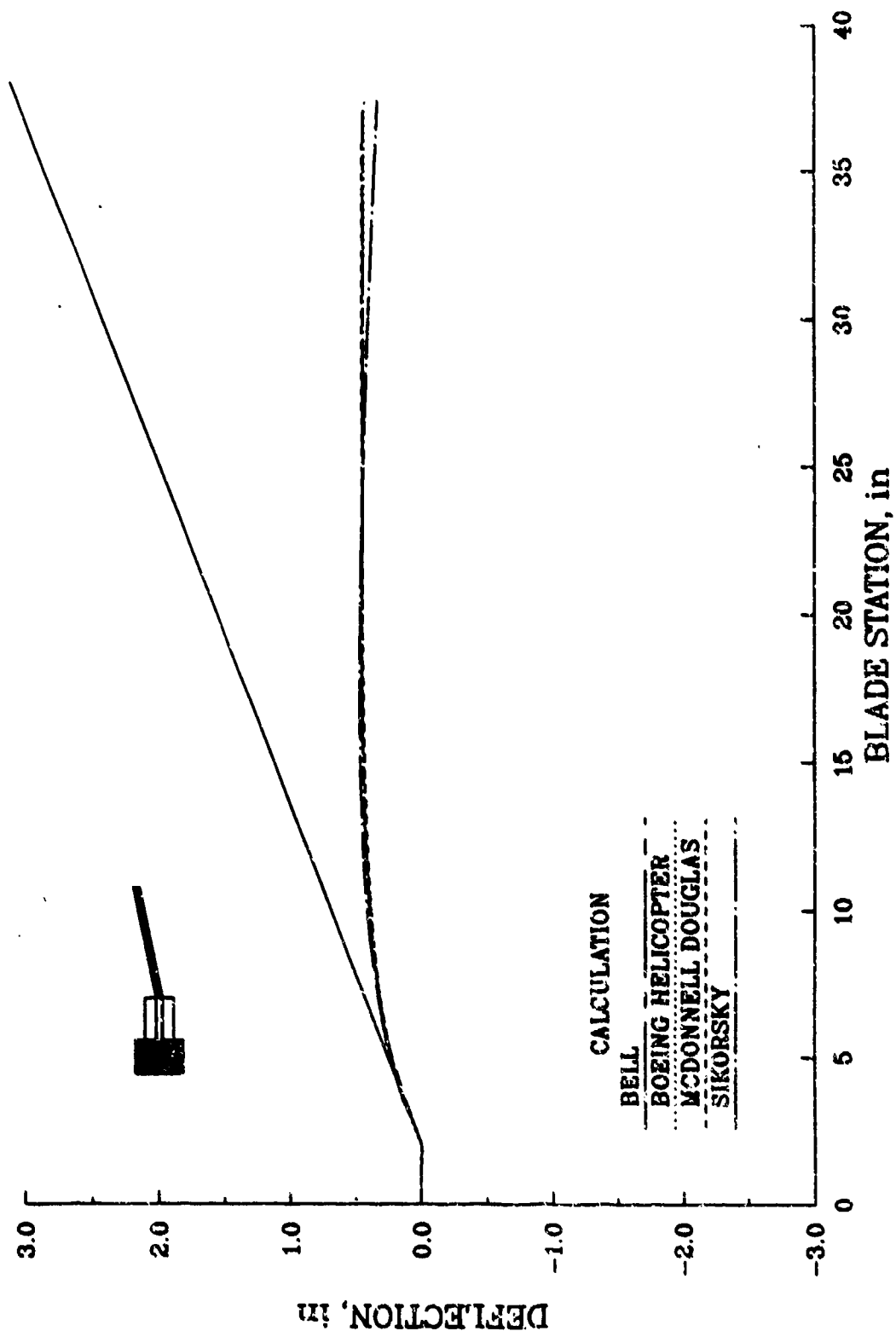


FLAP EQUILIBRIUM DEFLECTION - TASK 86g  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = -4 deg

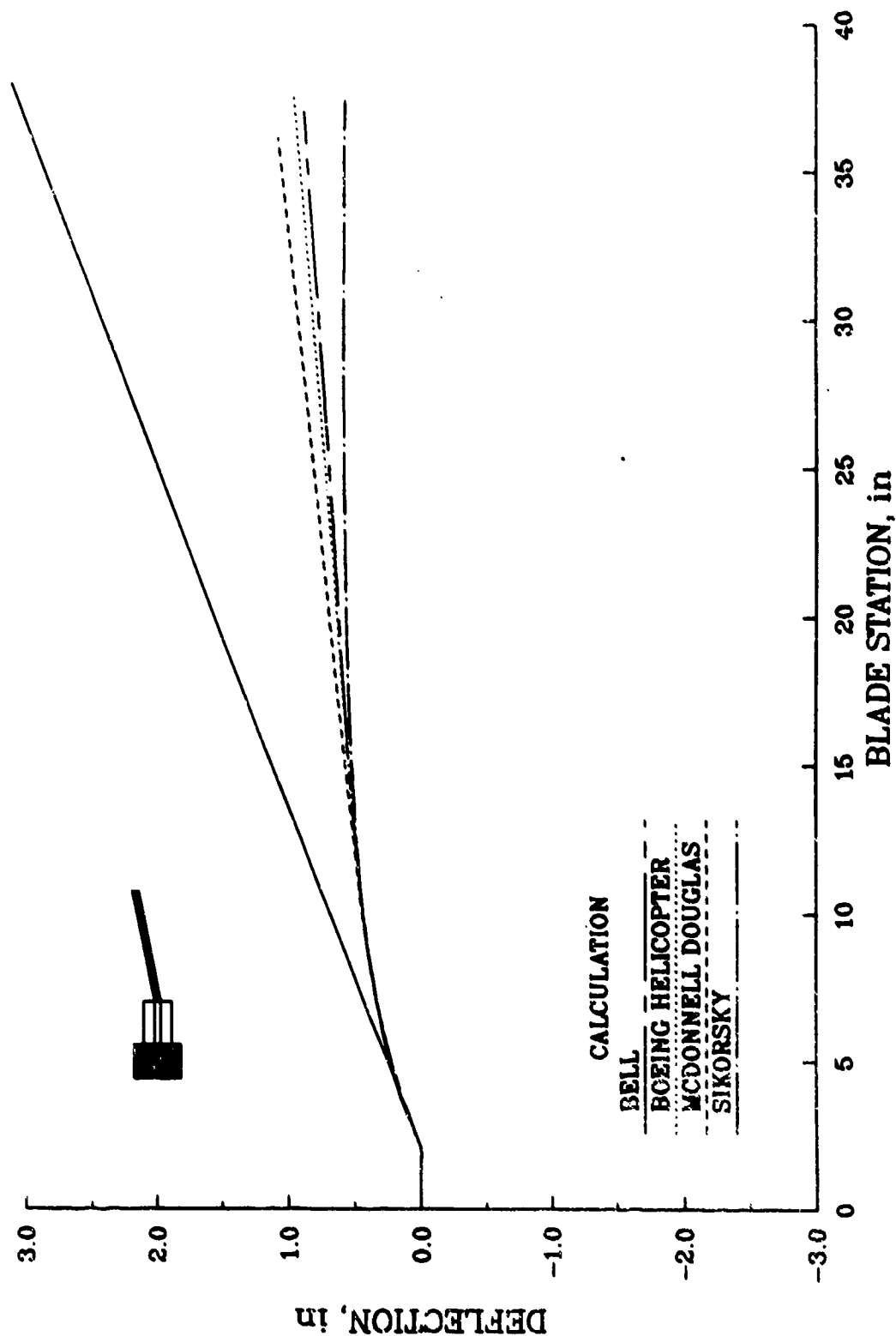




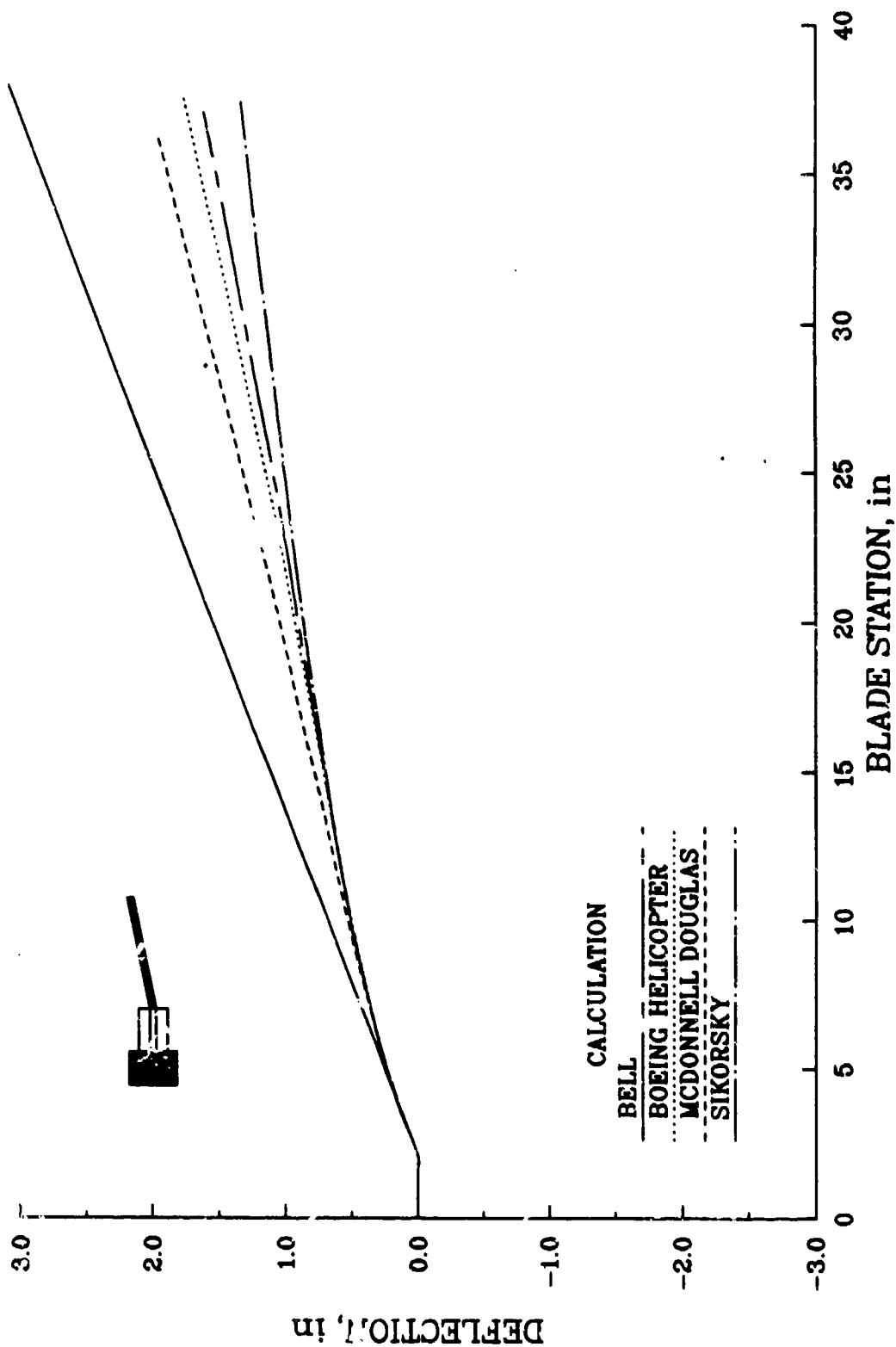
FLAP EQUILIBRIUM DEFLECTION - TASK 86g  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = 0 deg



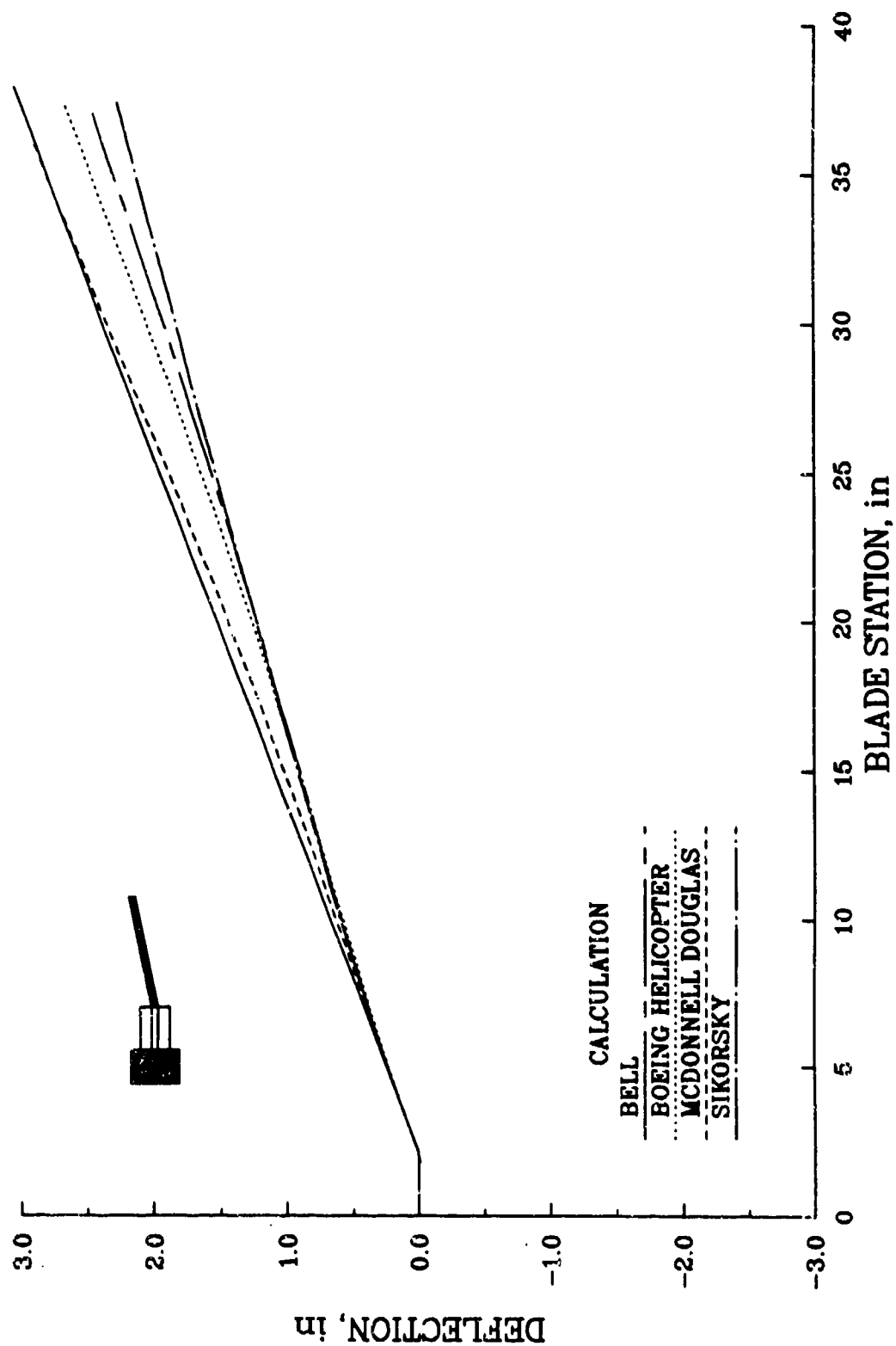
FLAP EQUILIBRIUM DEFLECTION - TASK 86g  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = 4 deg



FLAP EQUILIBRIUM DEFLECTION - TASK 86g  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = 8 deg



FLAP EQUILIBRIUM DEFLECTION - TASK 86g  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = 12 deg

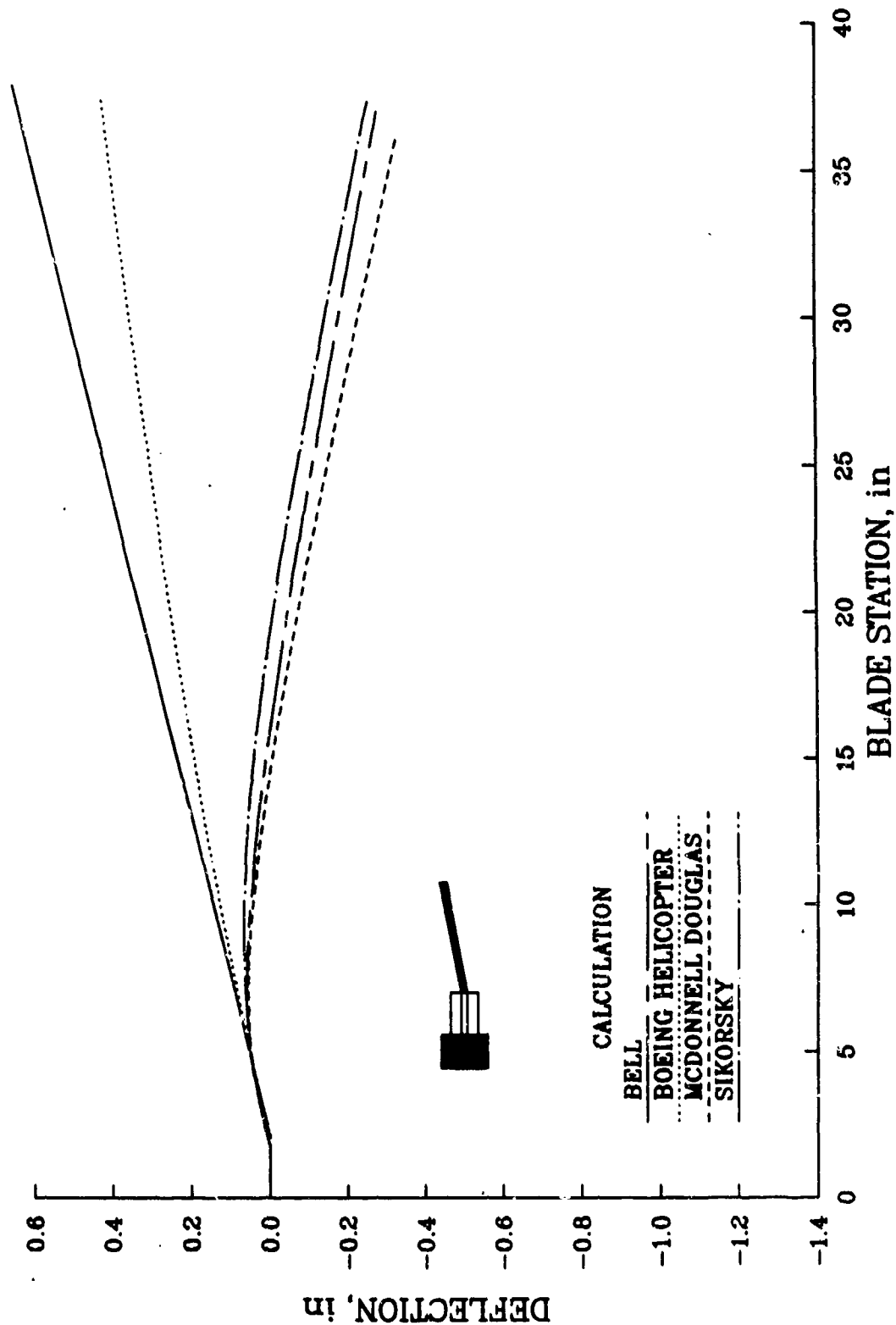


# LEAD-LAG EQUILIBRIUM DEFLECTION - TASK 86g

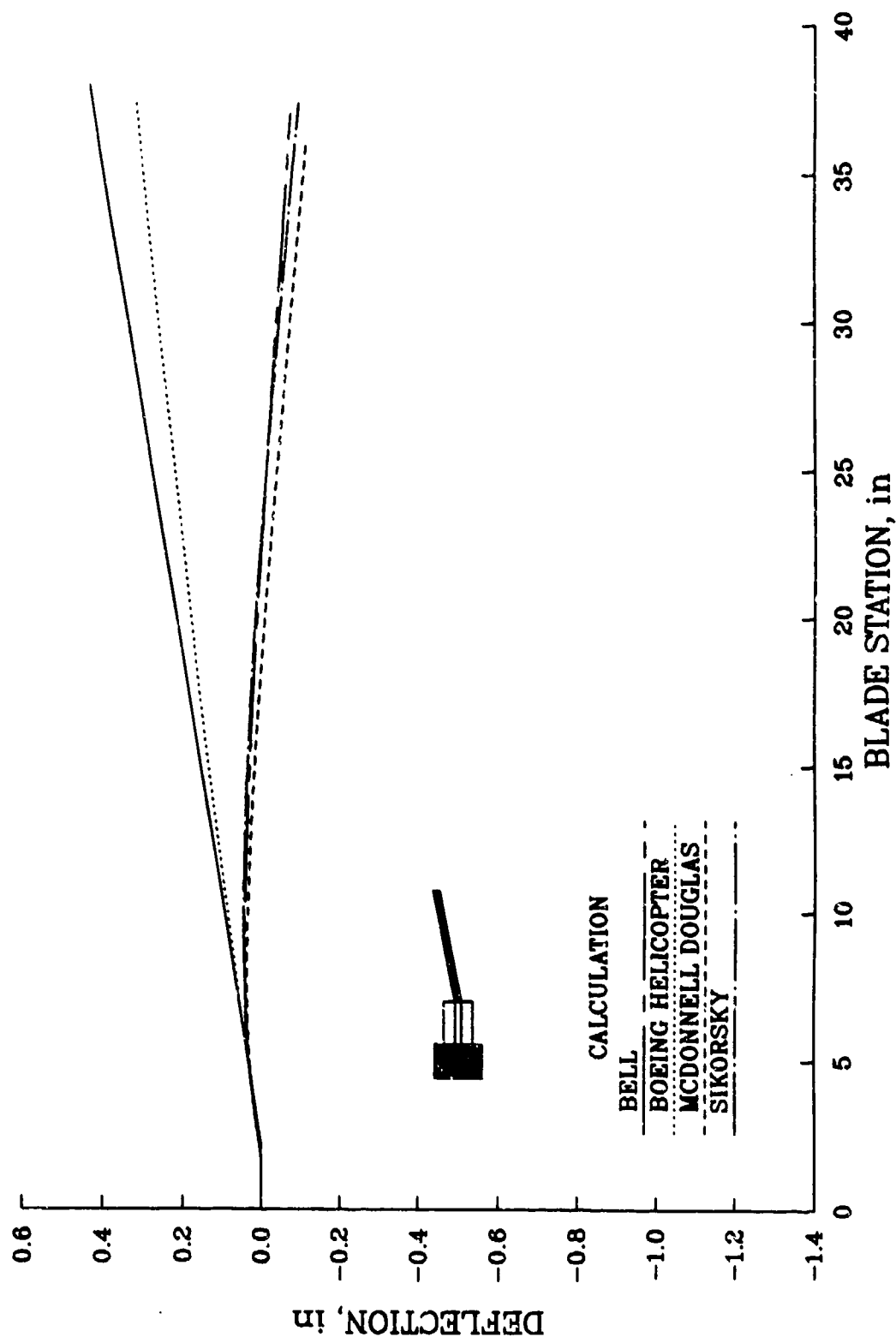
## LINEAR AERODYNAMIC COEFFICIENTS

### CASE 6 - TORSIONALLY SOFT ROTOR

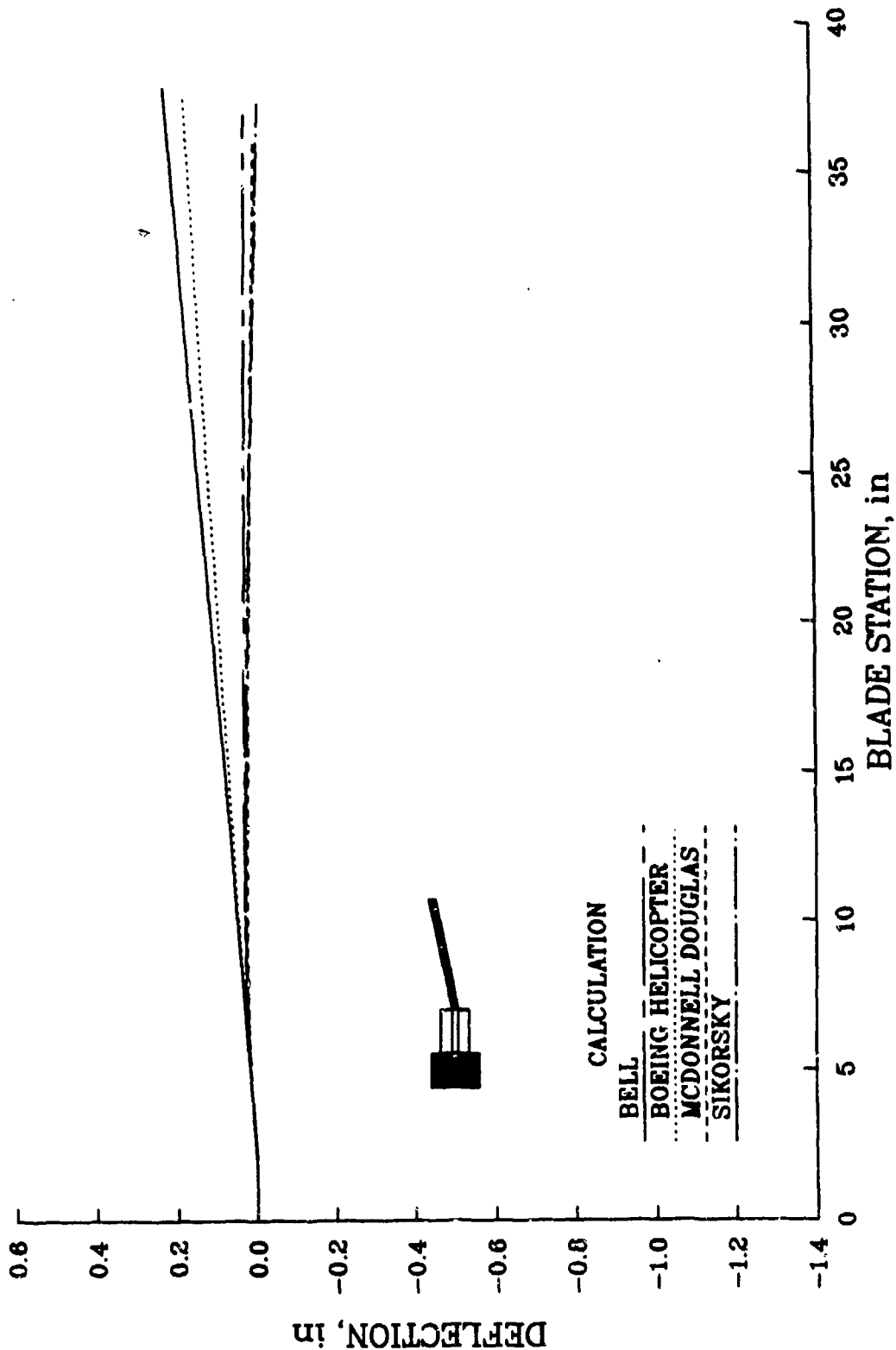
PITCH ANGLE = -12 deg



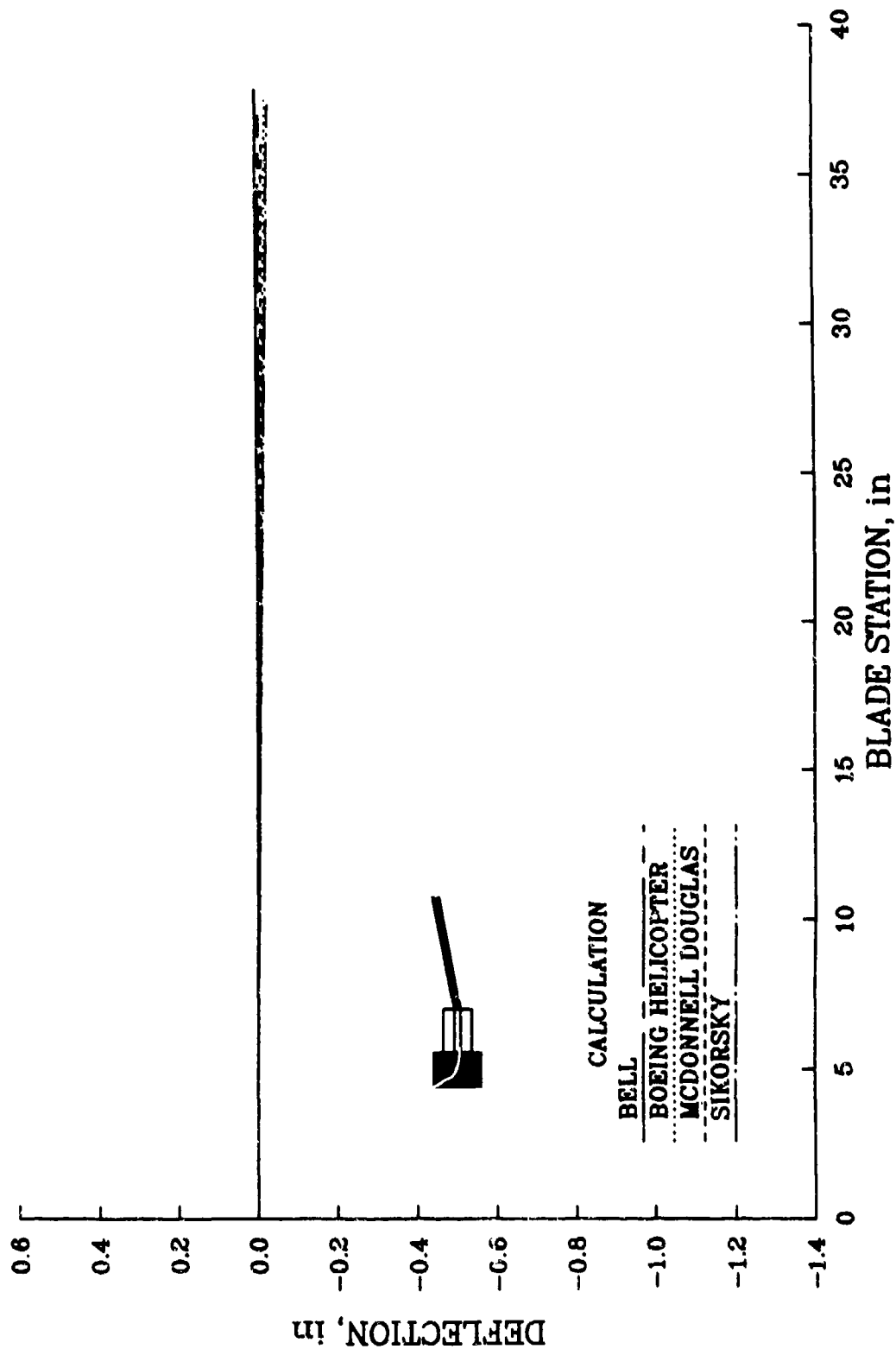
LEAD-LAG EQUILIBRIUM DEFLECTION -- TASK 86g  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 -- TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = -8 deg



LEAD-LAG EQUILIBRIUM DEFLECTION - TASK 86g  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = -4 deg

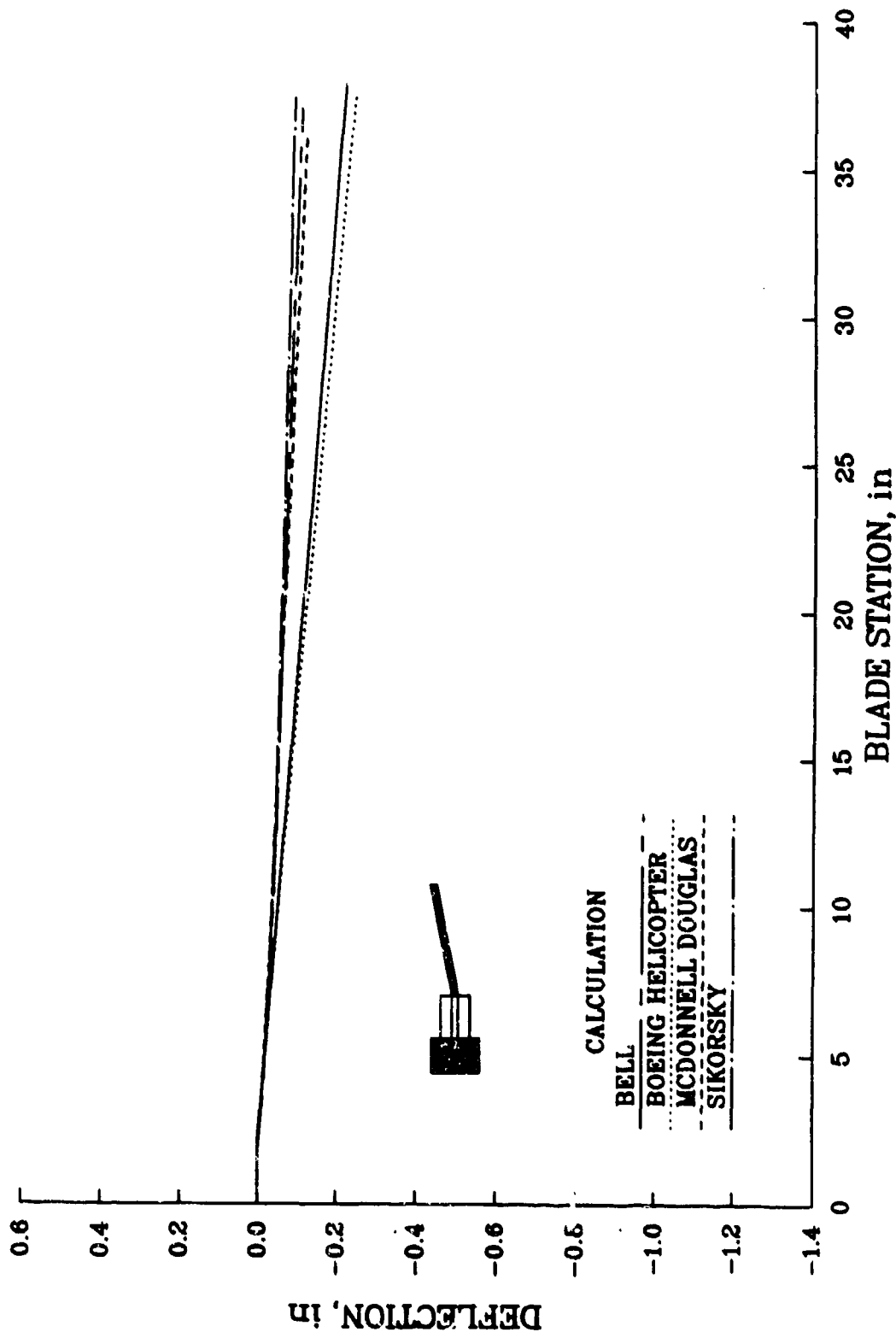


LEAD-LAG EQUILIBRIUM DEFLECTION - TASK 86g  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = 0 deg

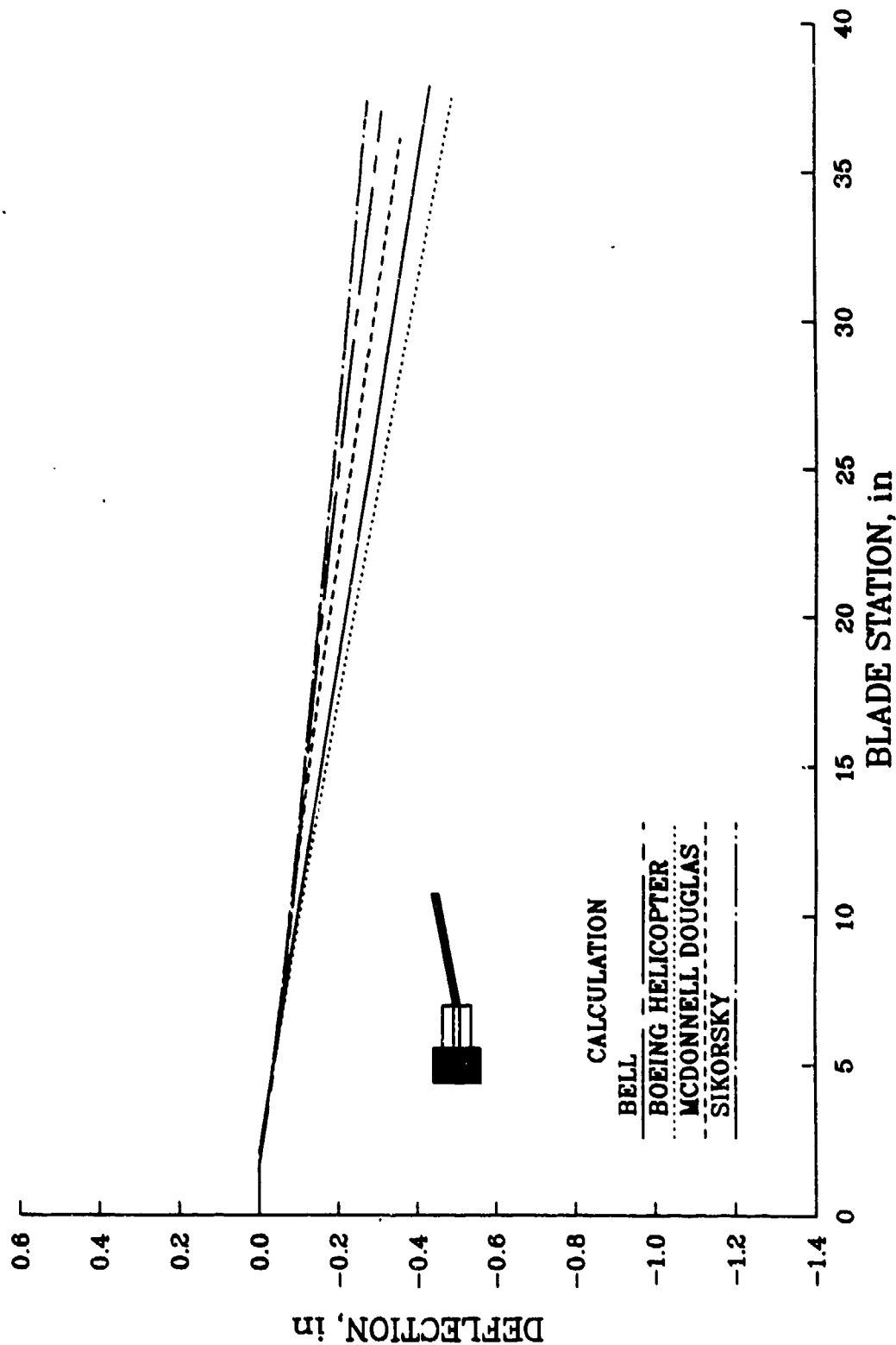




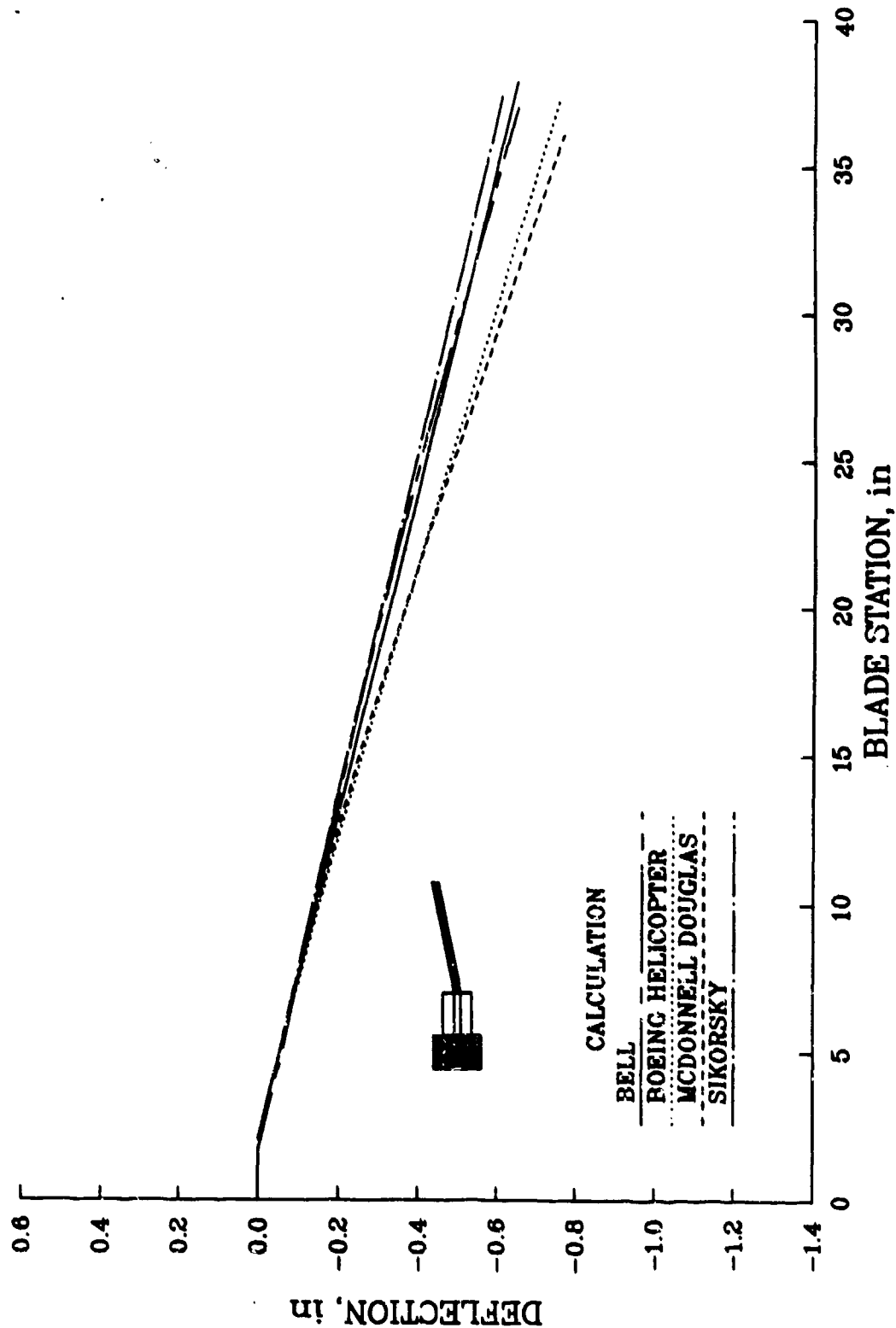
LEAD-LAG EQUILIBRIUM DEFLECTION - TASK 86g  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = 4 deg



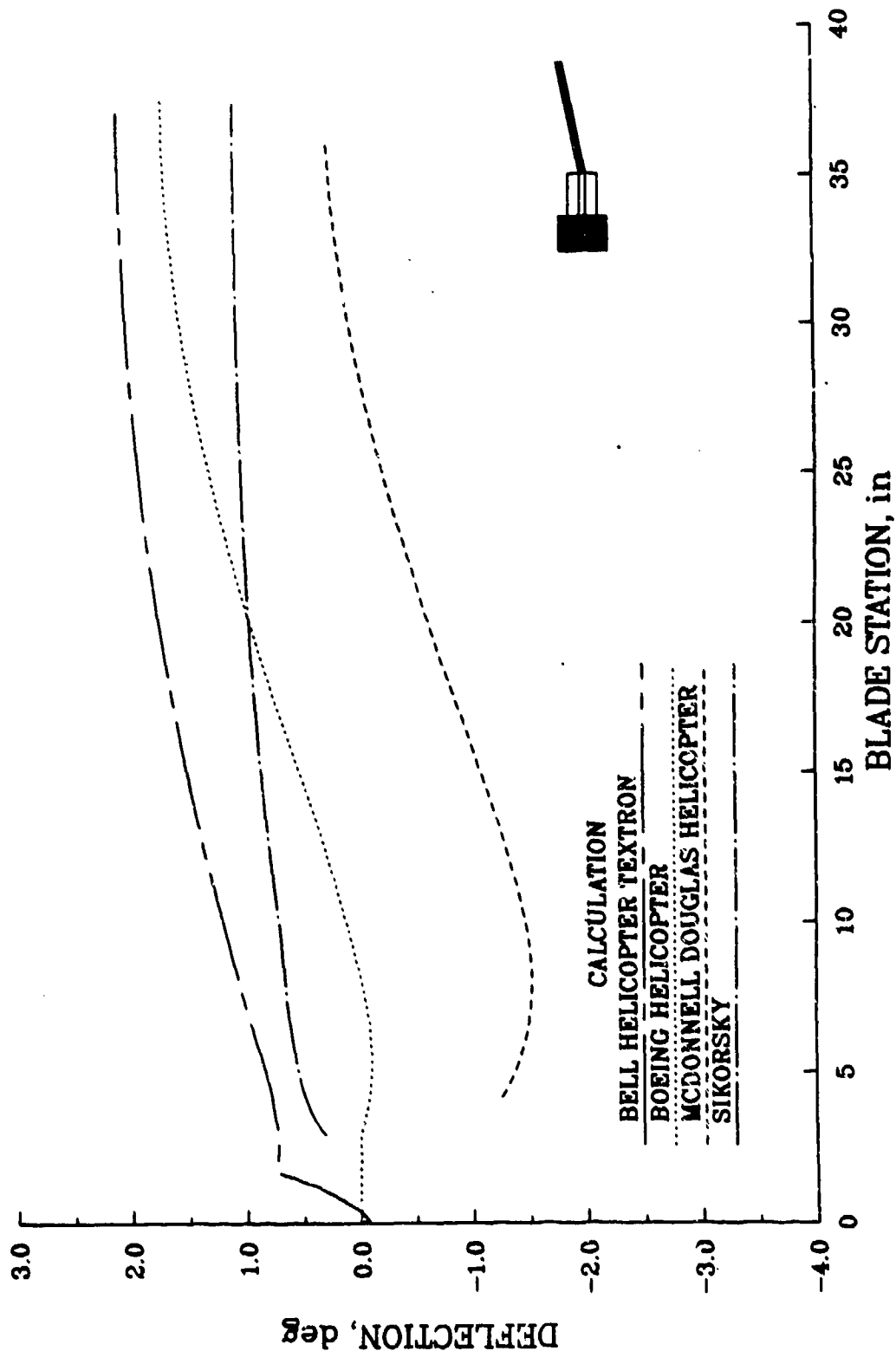
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 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = 8 deg



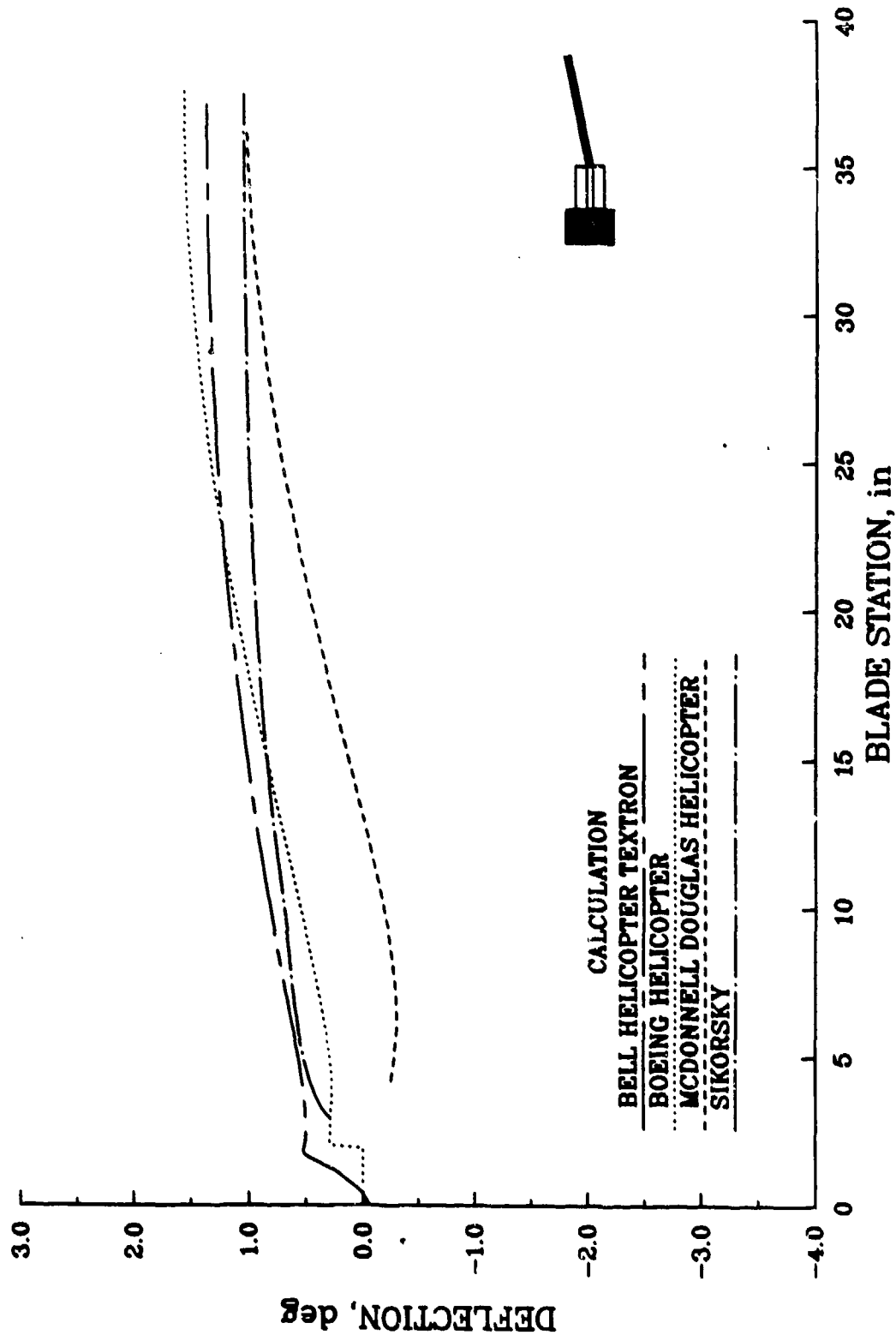
LEAD-LAG EQUILIBRIUM DEFLECTION - TASK 86g  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = 12 deg



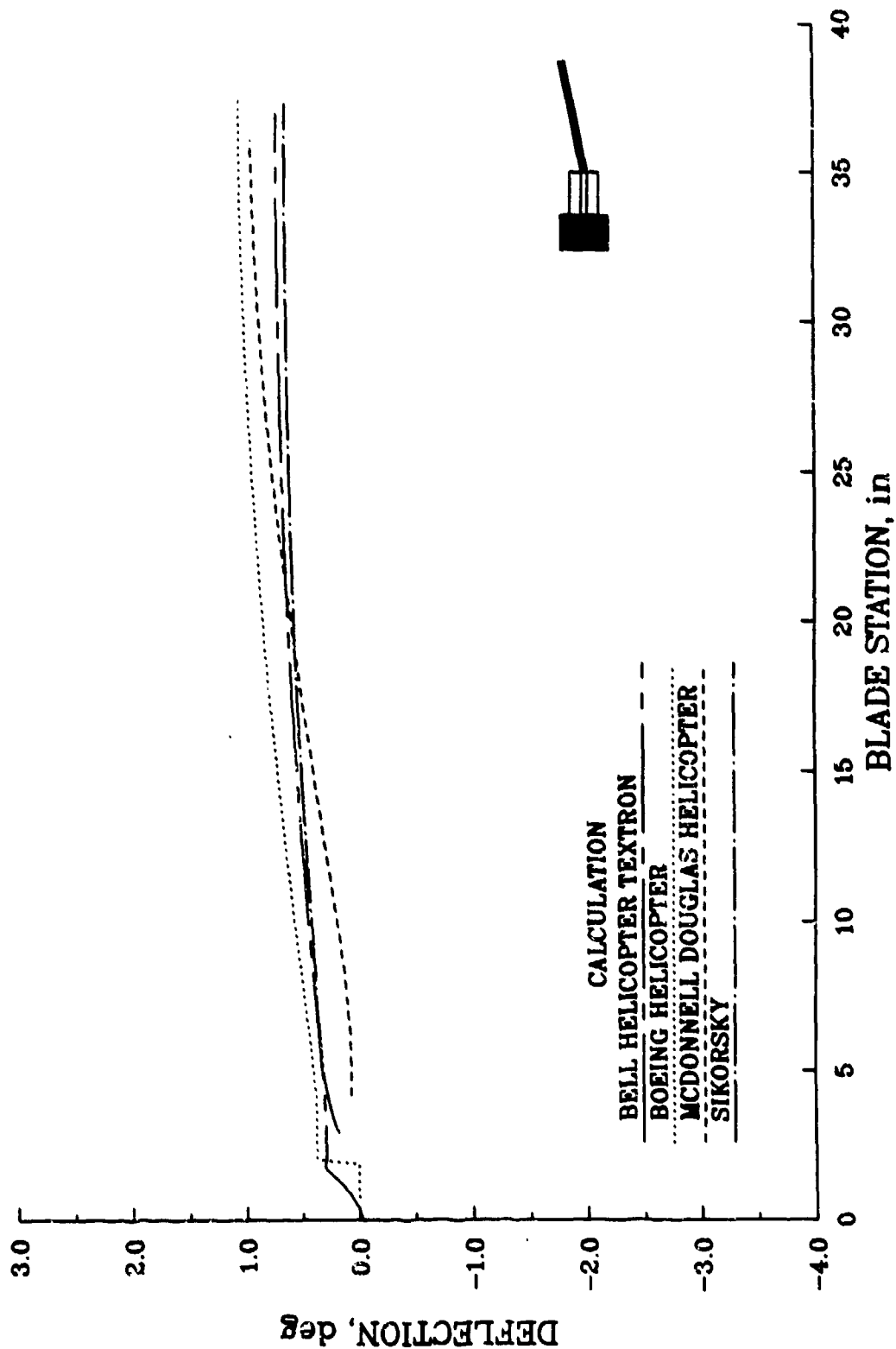
TORSION EQUILIBRIUM DEFLECTION - TASK 86g  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = -12 deg



TORSION EQUILIBRIUM DEFLECTION - TASK 86g  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = -8 deg



**TORSION EQUILIBRIUM DEFLECTION - TASK 86g**  
**LINEAR AERODYNAMIC COEFFICIENTS**  
**CASE 6 - TORSIONALLY SOFT ROTOR**  
**PITCH ANGLE = -4 deg**

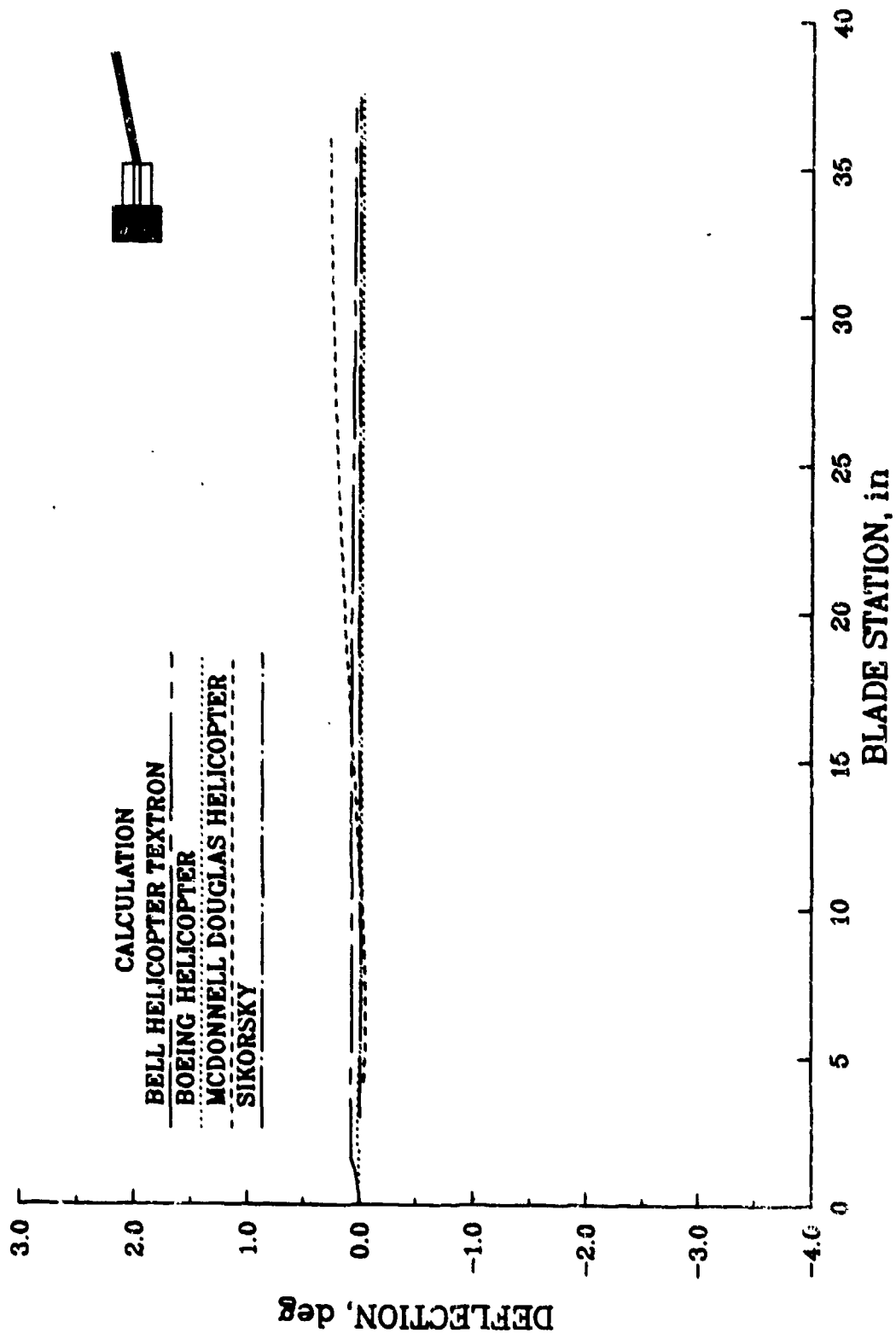


# TORSION EQUILIBRIUM DEFLECTION - TASK 86g

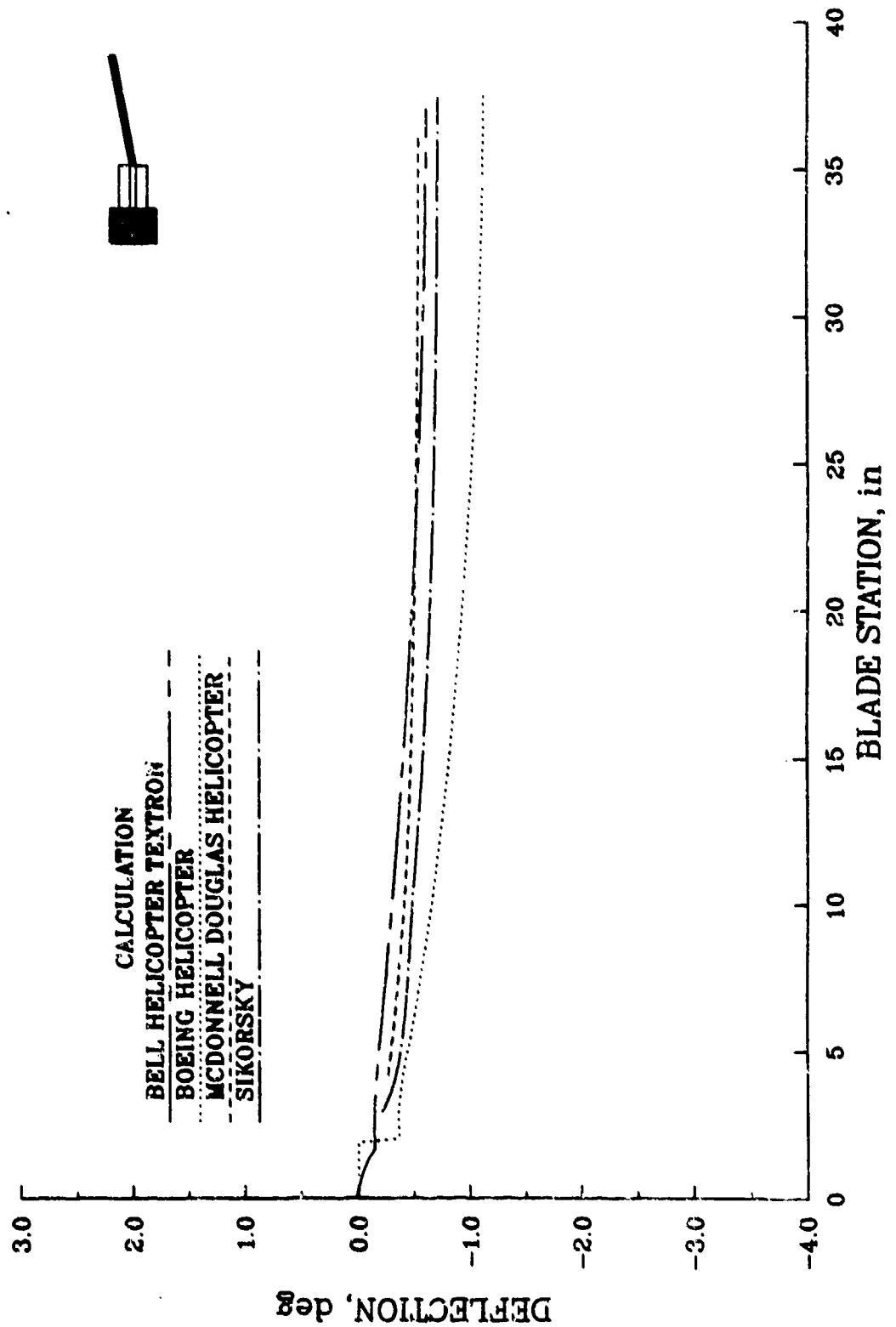
## LINEAR AERODYNAMIC COEFFICIENTS

### CASE 6 - TORSIONALLY SOFT ROTOR

PITCH ANGLE = 0 deg



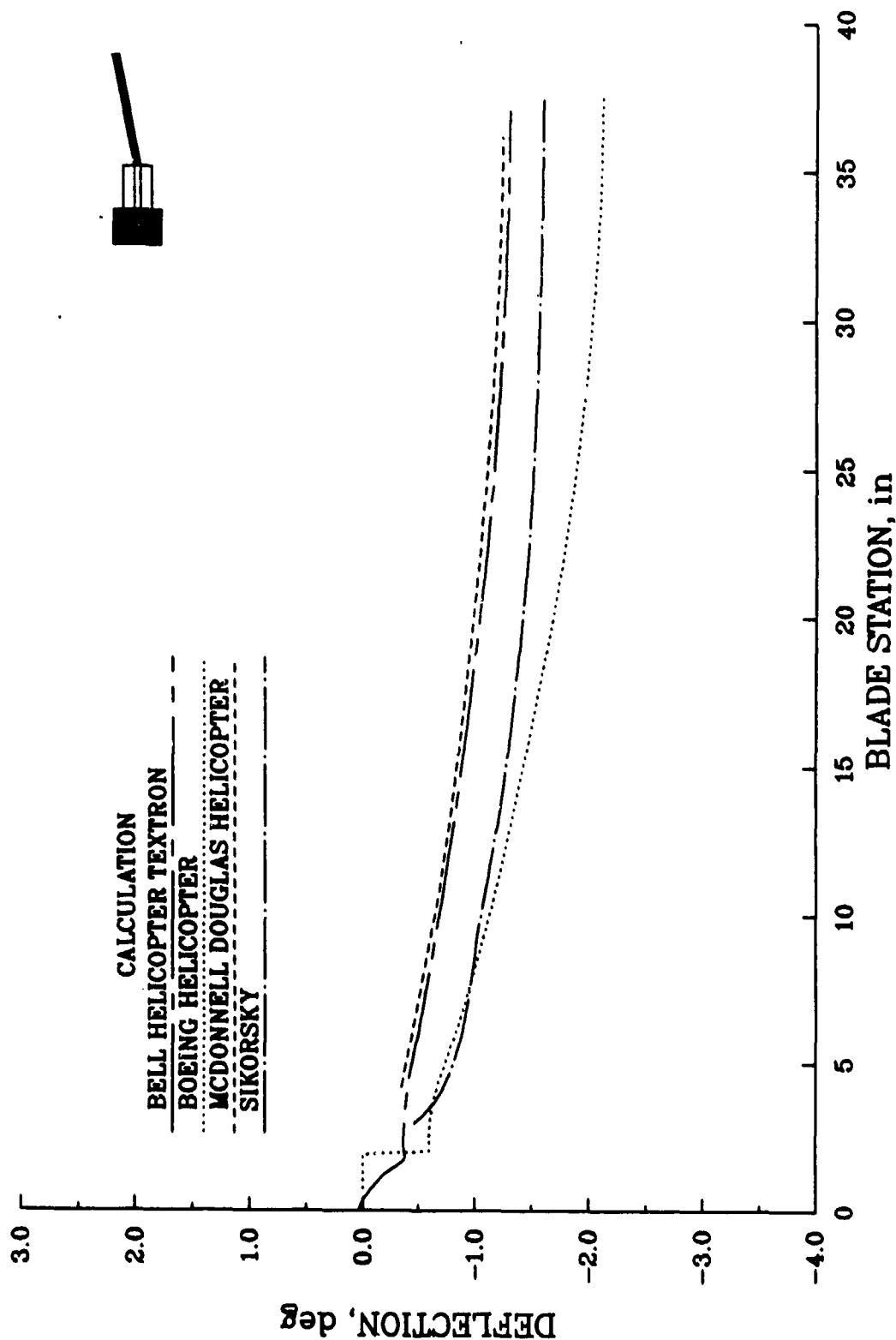
TORSION EQUILIBRIUM DEFLECTION - TASK 86g  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = 4 deg



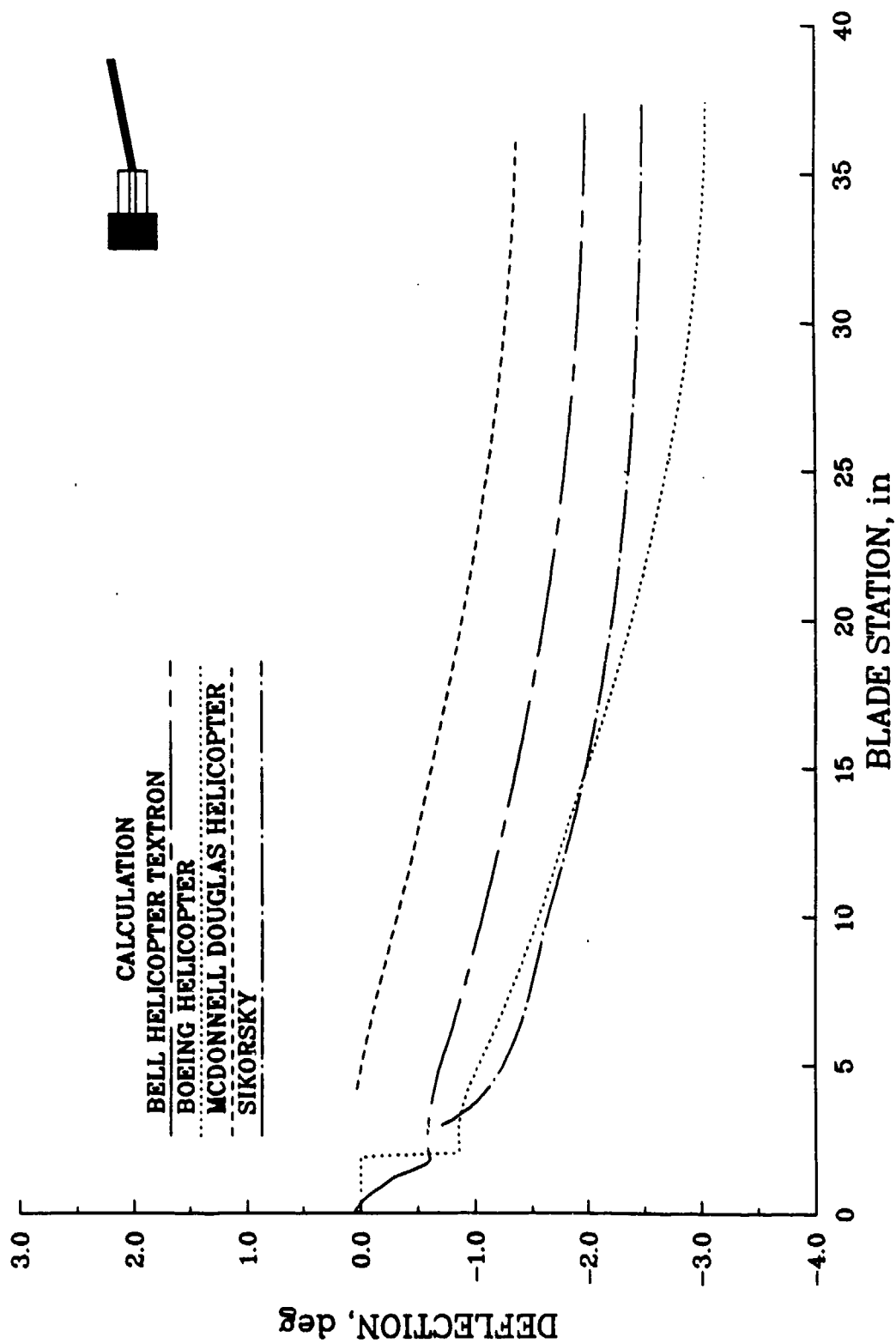


TORSION EQUILIBRIUM DEFLECTION - TASK 86g  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR

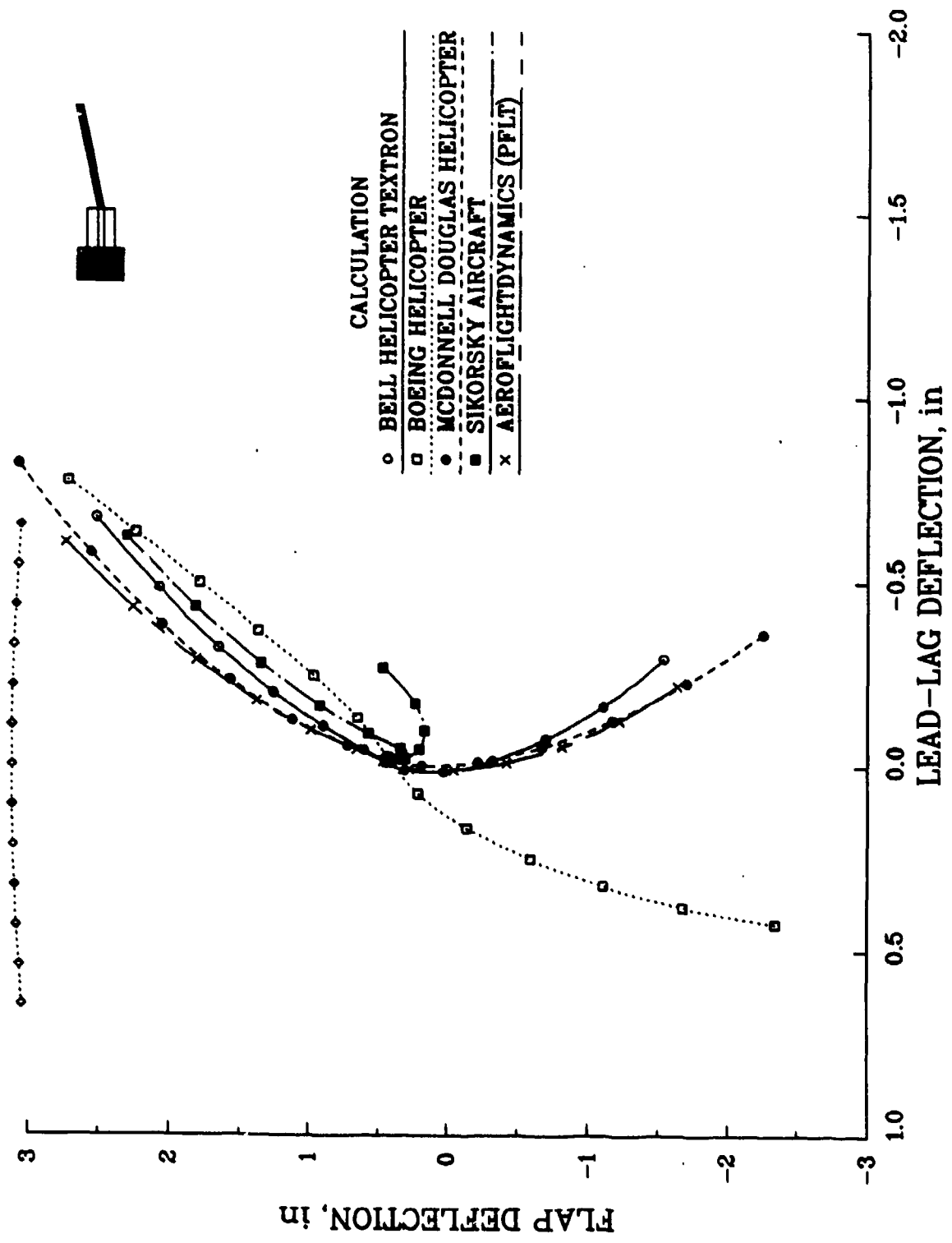
PITCH ANGLE = 8 deg



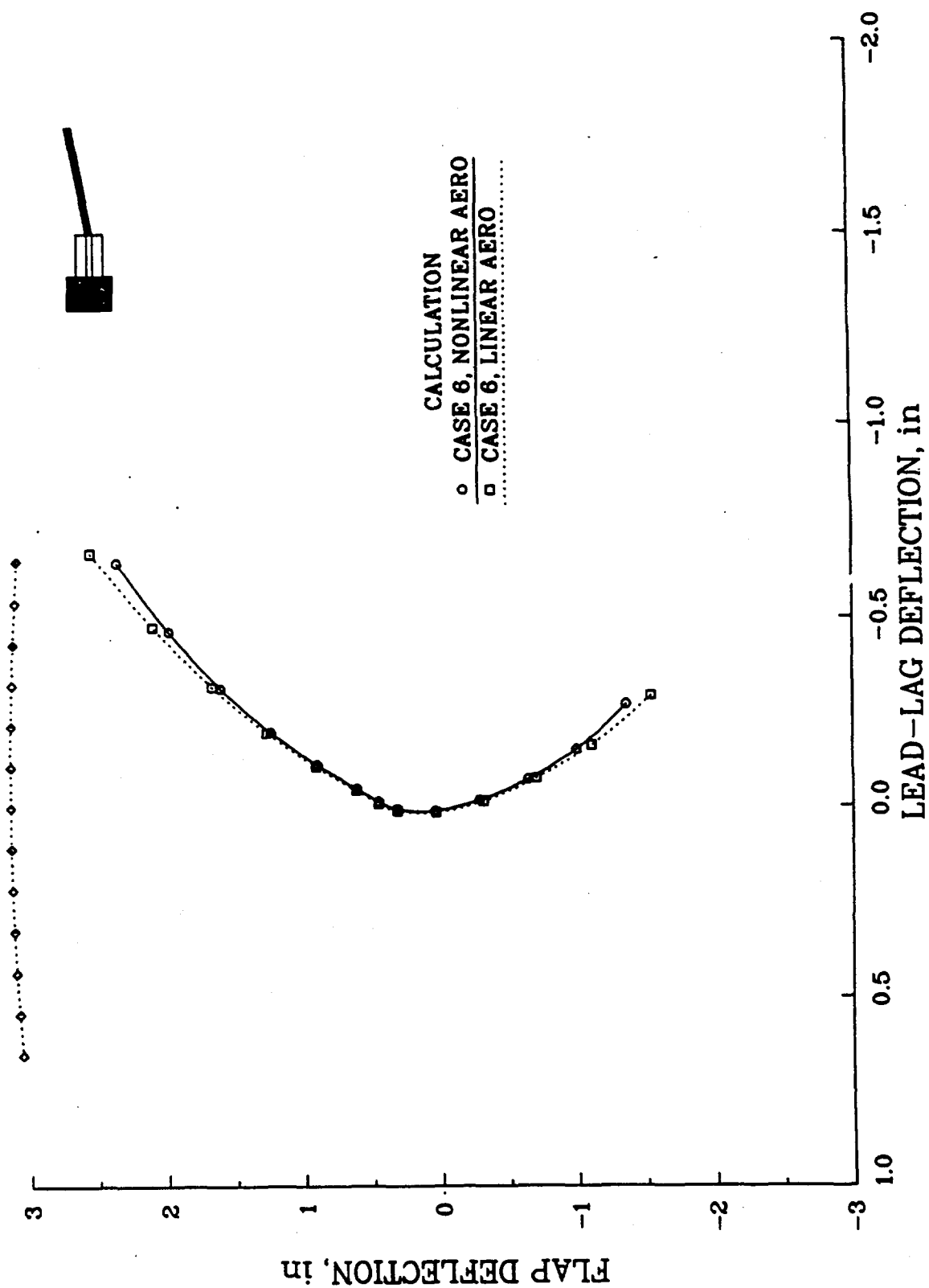
**TORSION EQUILIBRIUM DEFLECTION - TASK 86g**  
**LINEAR AERODYNAMIC COEFFICIENTS**  
**CASE 6 - TORSIONALLY SOFT ROTOR**  
**PITCH ANGLE = 12 deg**



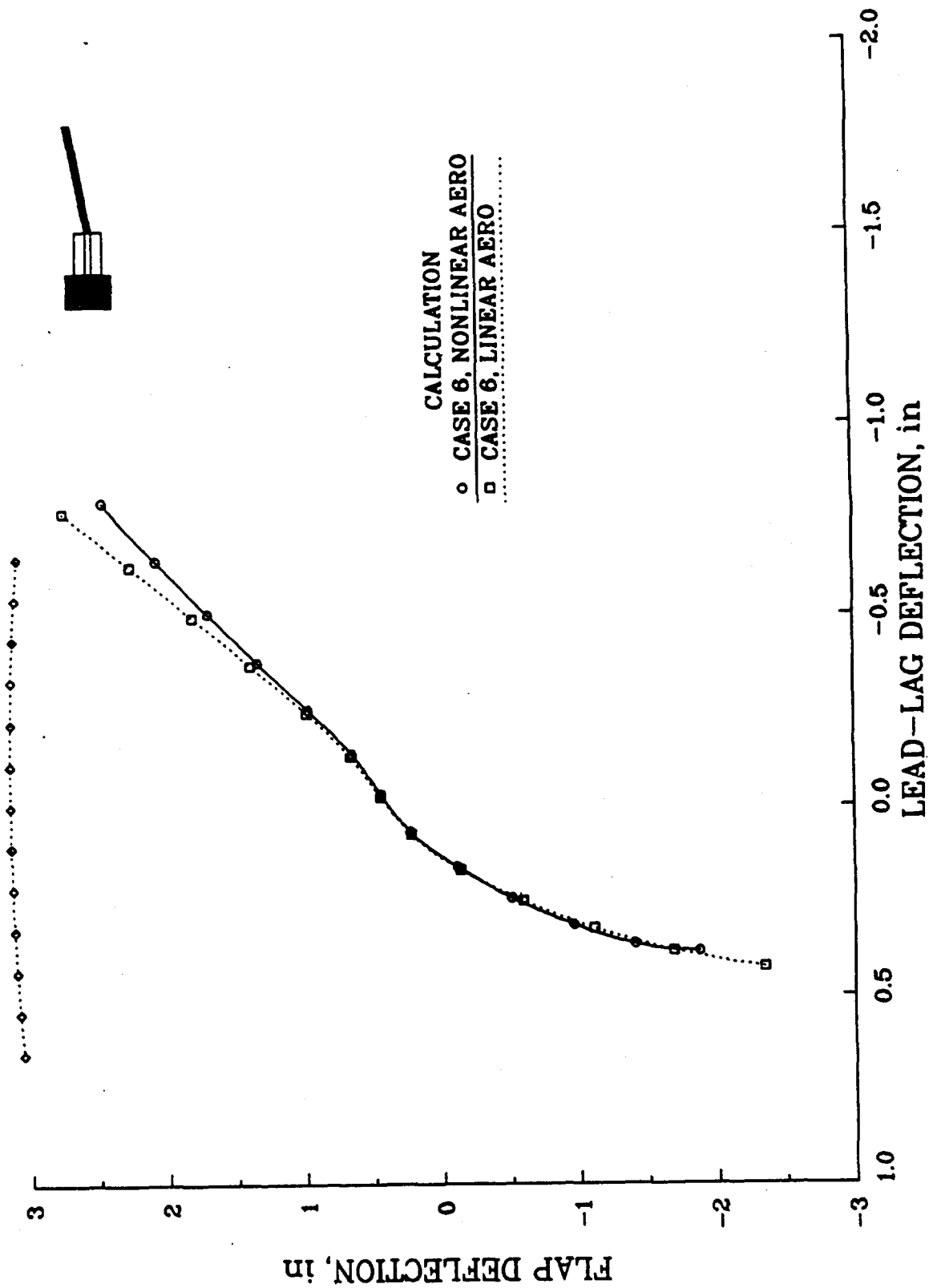
BLADE TIP DEFLECTION - TASK 86g  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR



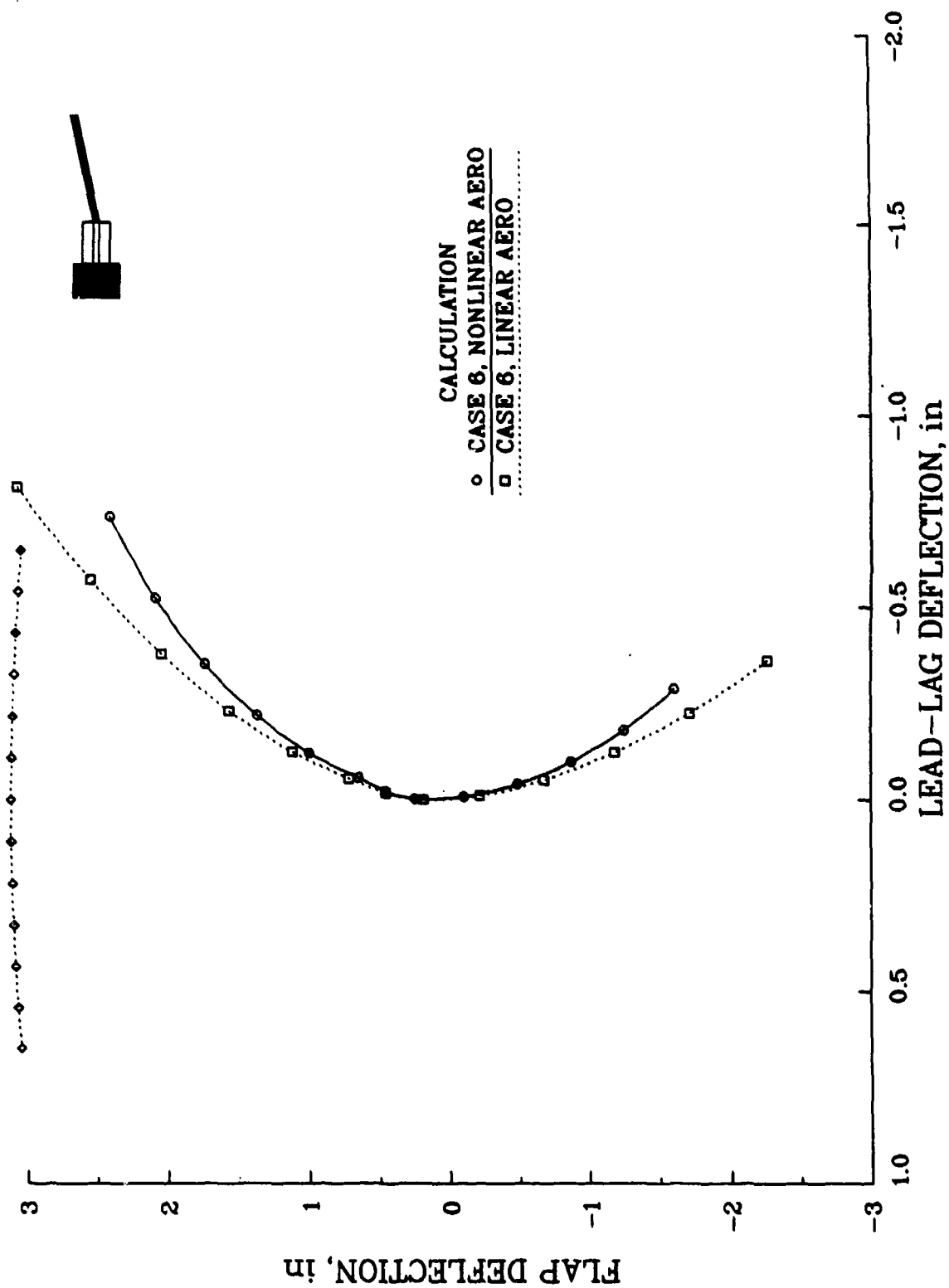
BLADE TIP DEFLECTION  
TORSIONALLY SOFT ROTOR  
BELL HELICOPTER TEXTRON



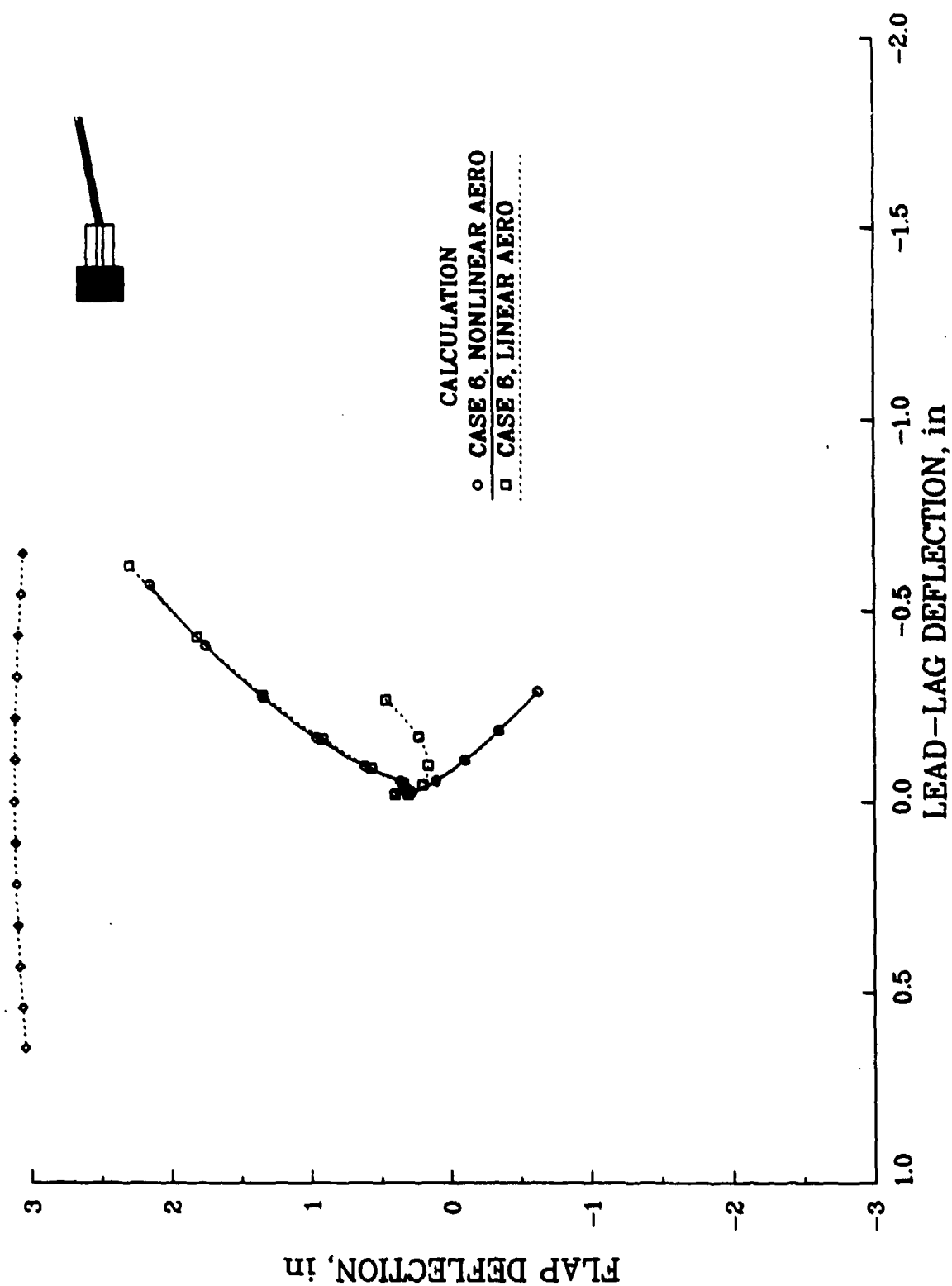
# BLADE TIP DEFLECTION TORSIONALLY SOFT ROTOR BOEING HELICOPTER



BLADE TIP DEFLECTION  
TORSIONALLY SOFT ROTOR  
MCDONNELL DOUGLAS HELICOPTER

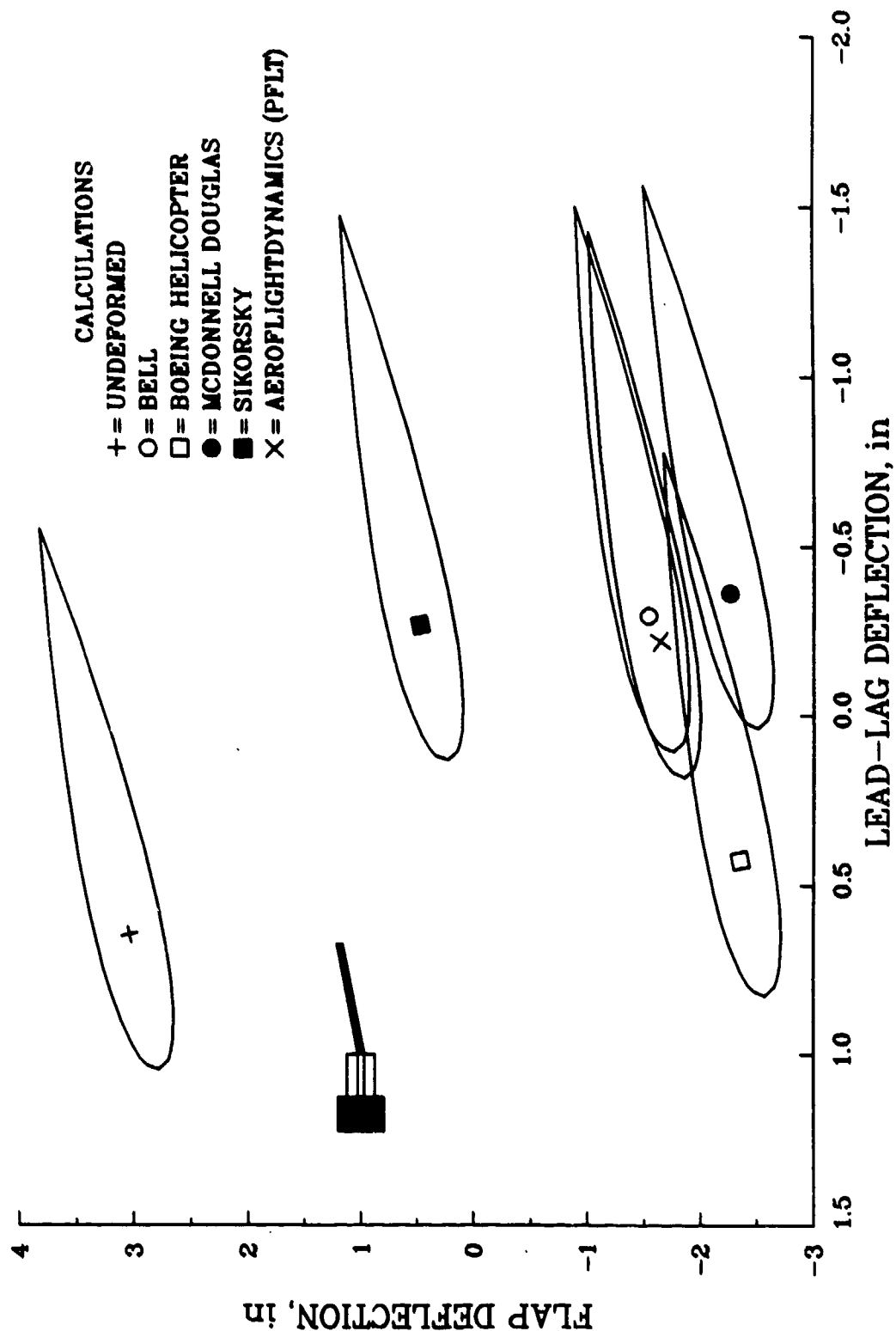


# BLADE TIP DEFLECTION TORSIONALLY SOFT ROTOR SIKORSKY AIRCRAFT



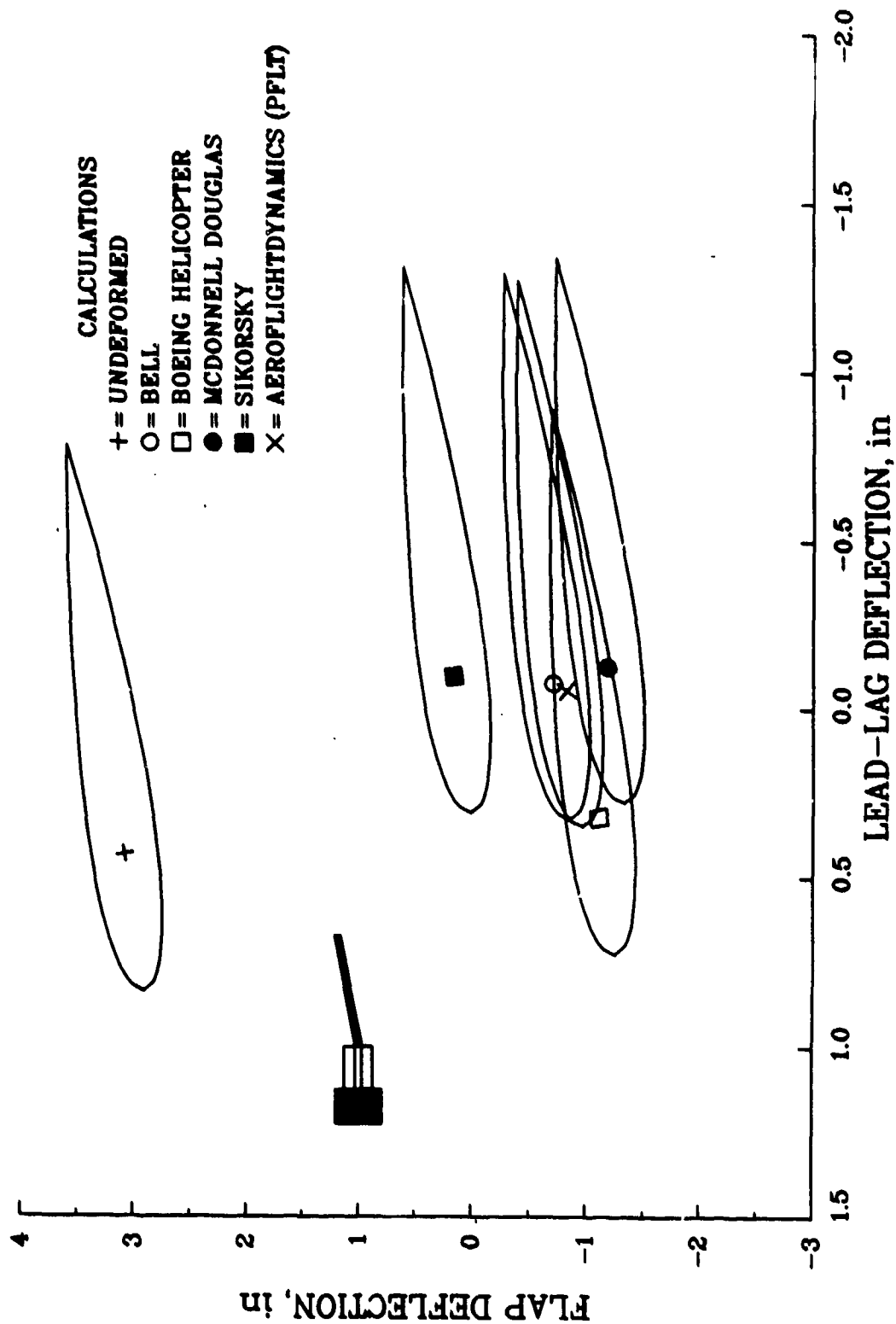
BLADE TIP DEFLECTION - TASK 86g  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR

PITCH ANGLE = -12 deg

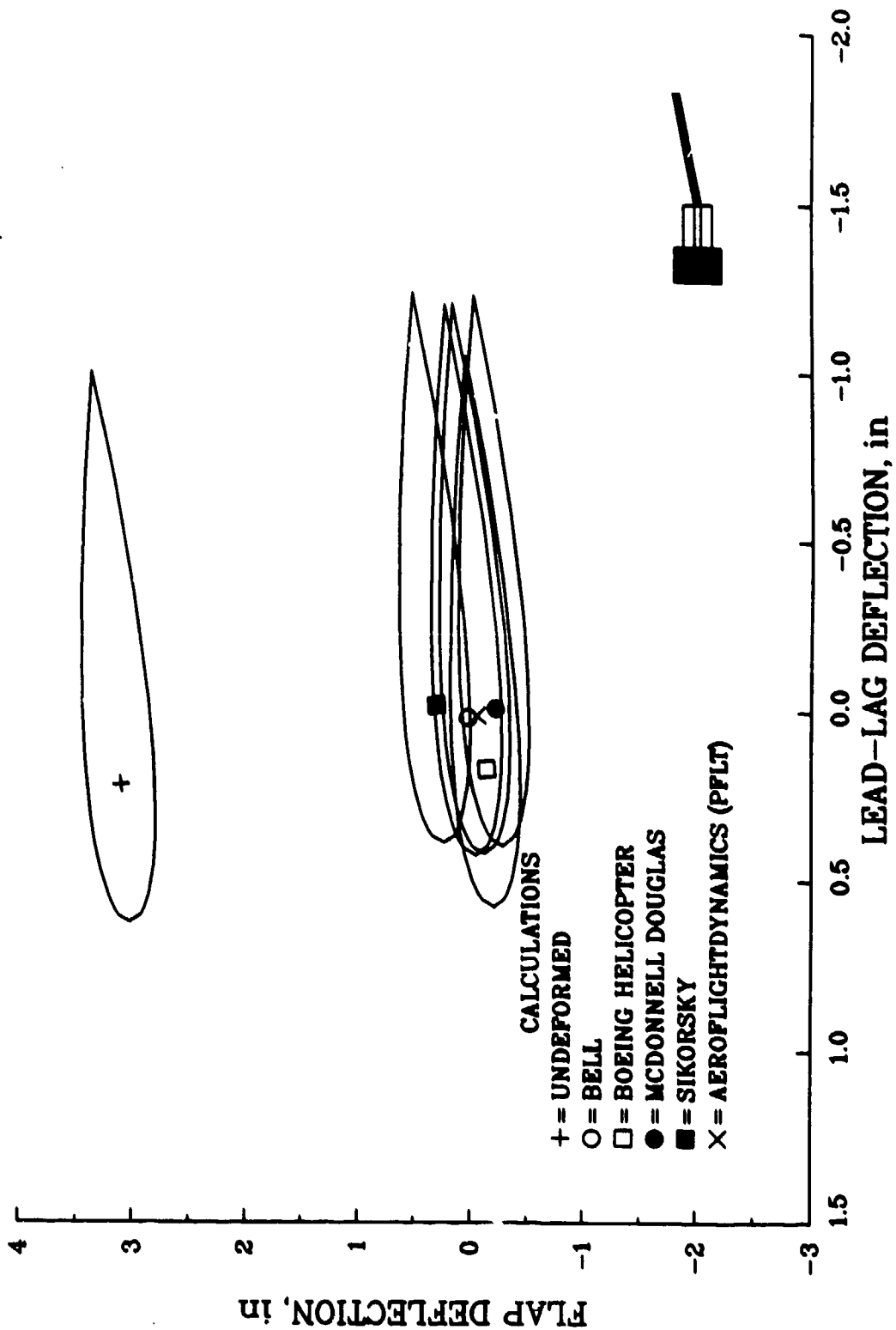




BLADE TIP DEFLECTION - TASK 86g  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE - -8 deg

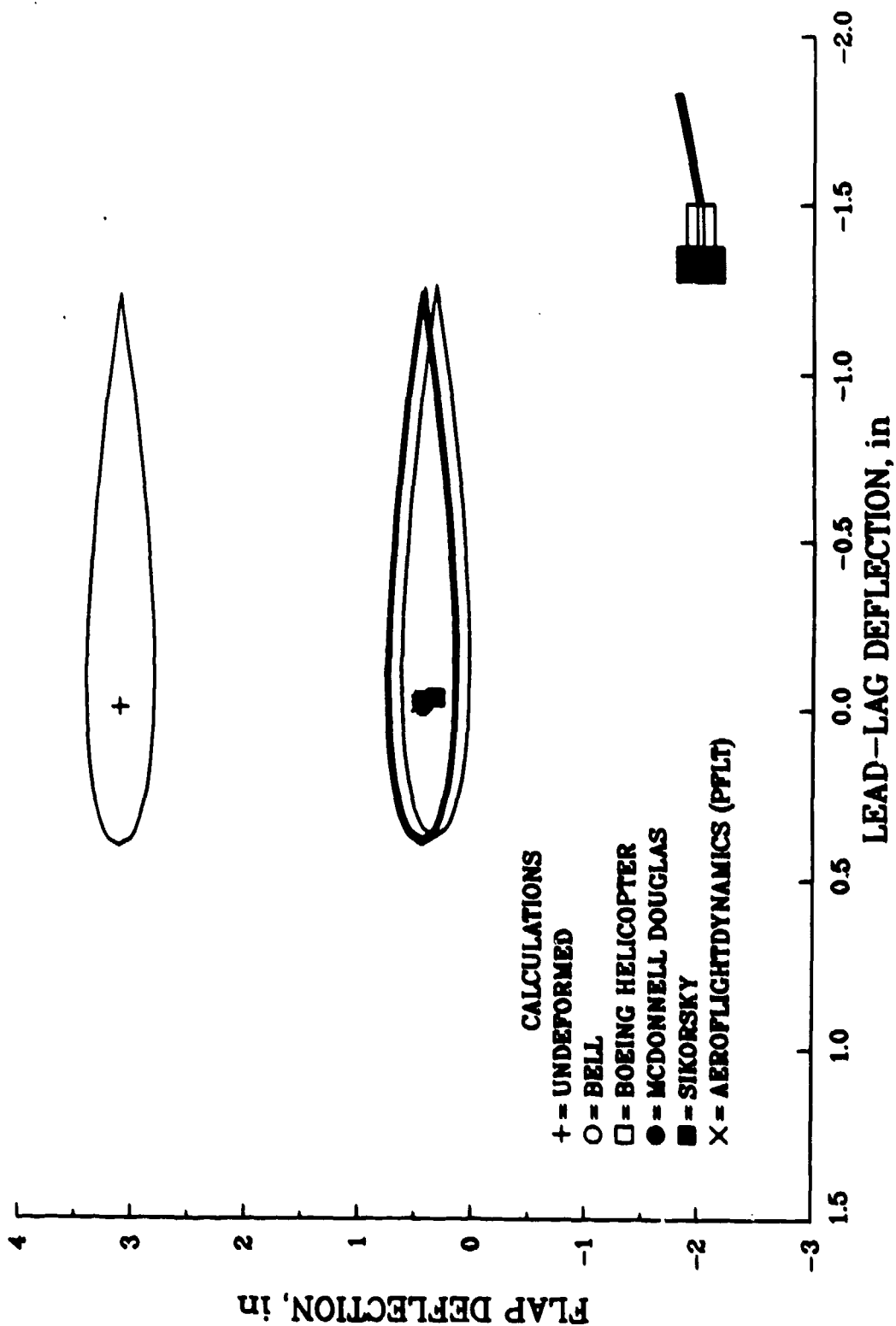


BLADE TIP DEFLECTION - TASK 86g  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = -4 deg

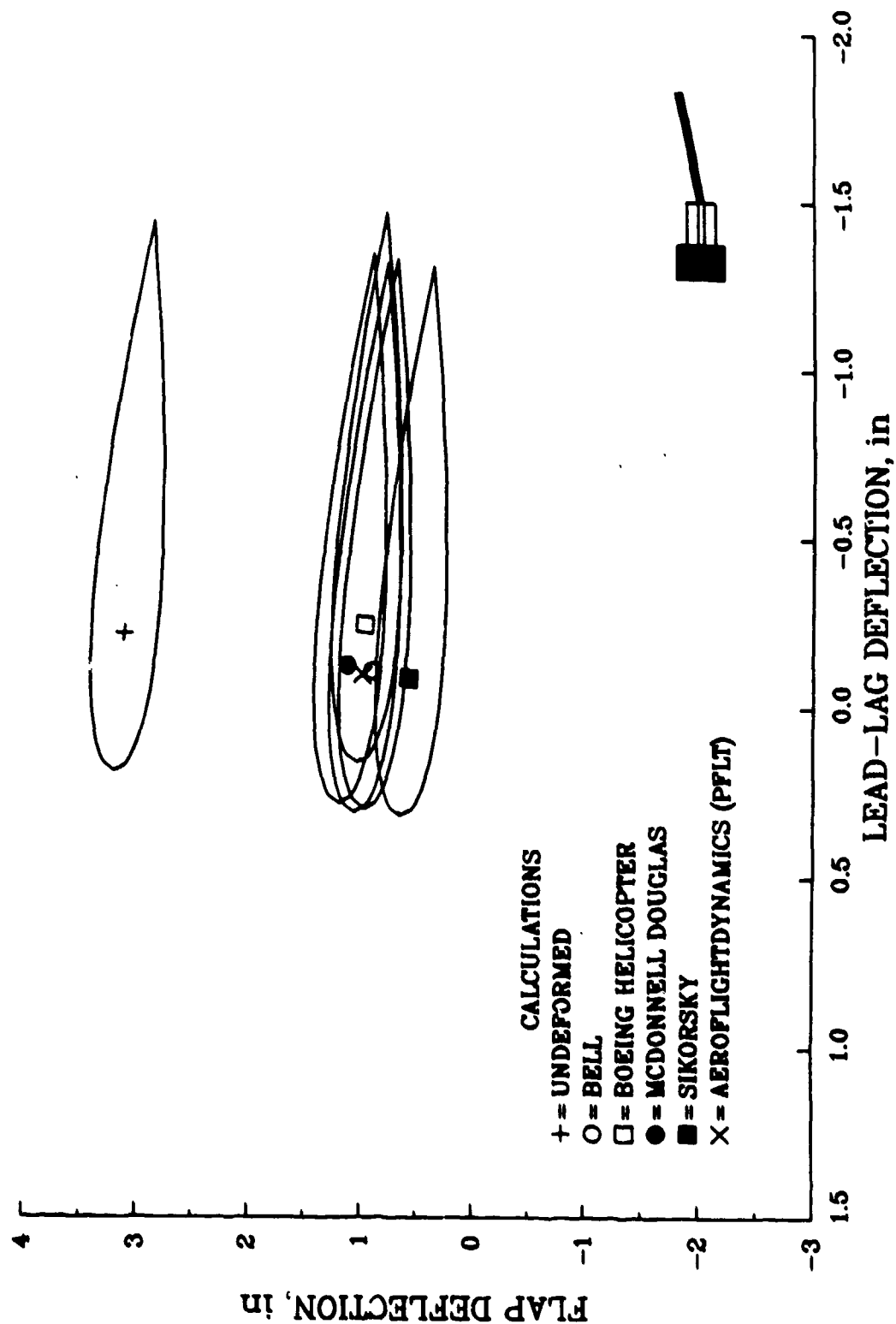


BLADE TIP DEFLECTION - TASK 86g  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR

PITCH ANGLE = 0 deg

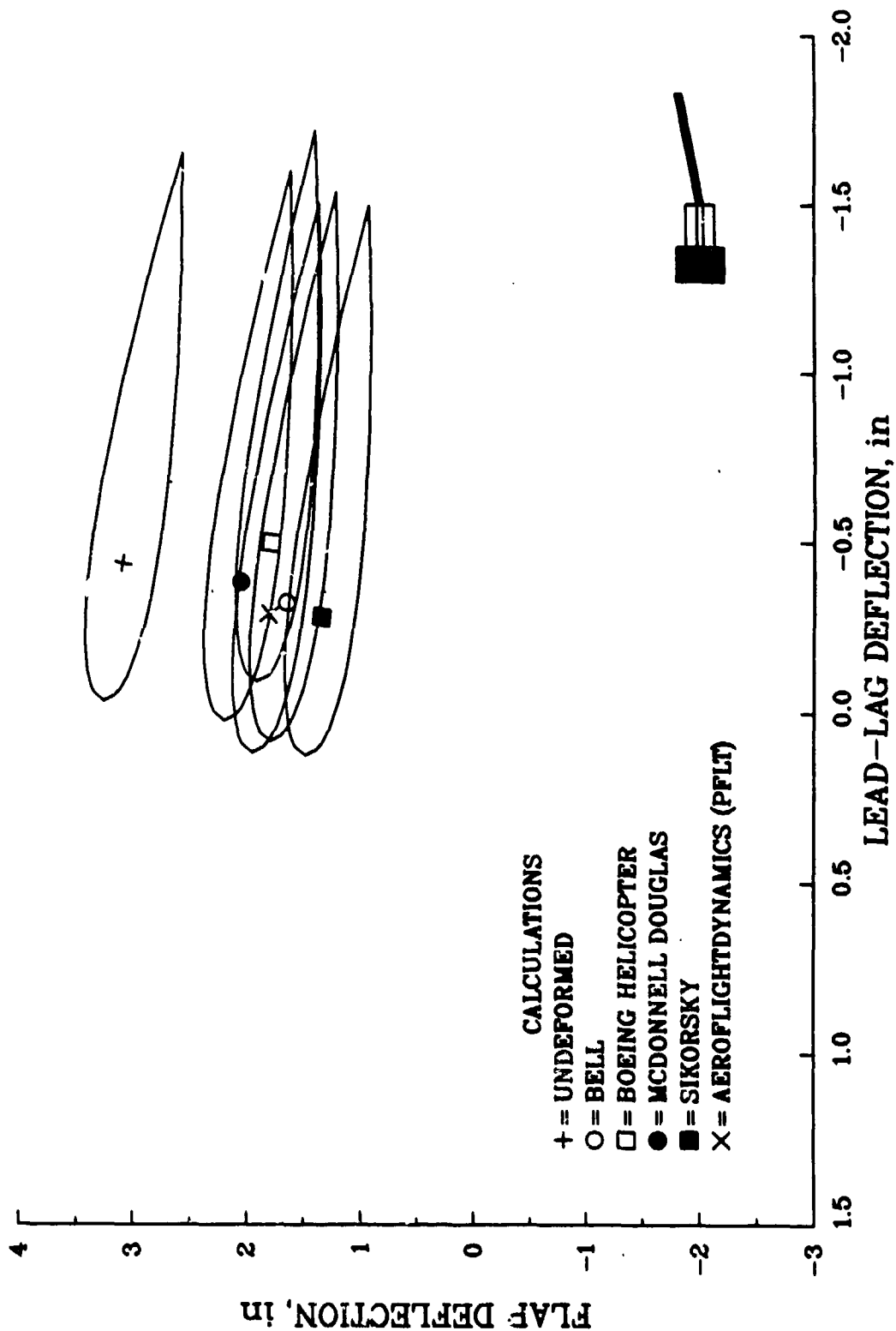


BLADE TIP DEFLECTION - TASK 86g  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = 4 deg

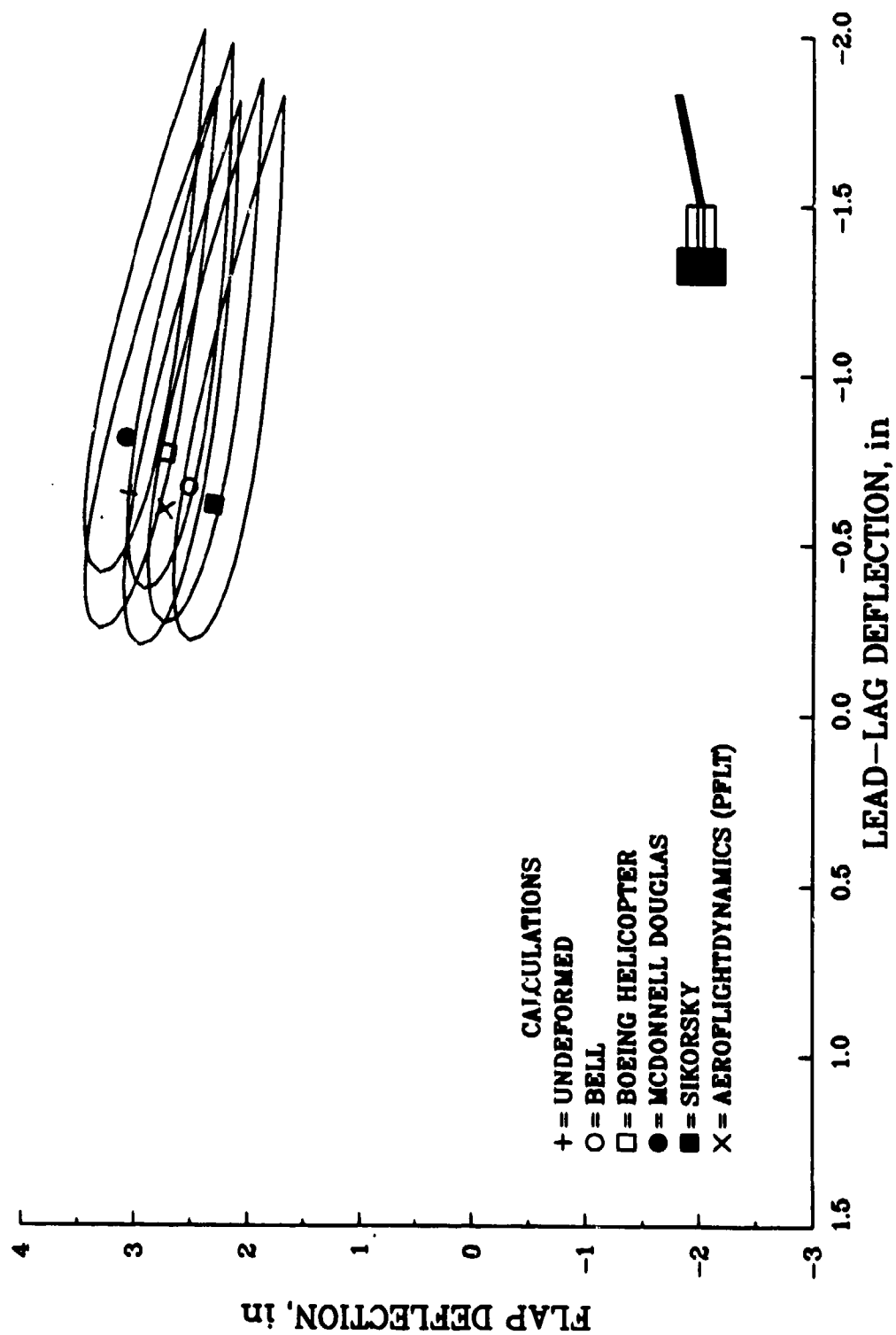


BLADE TIP DEFLECTION - TASK 86g  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR

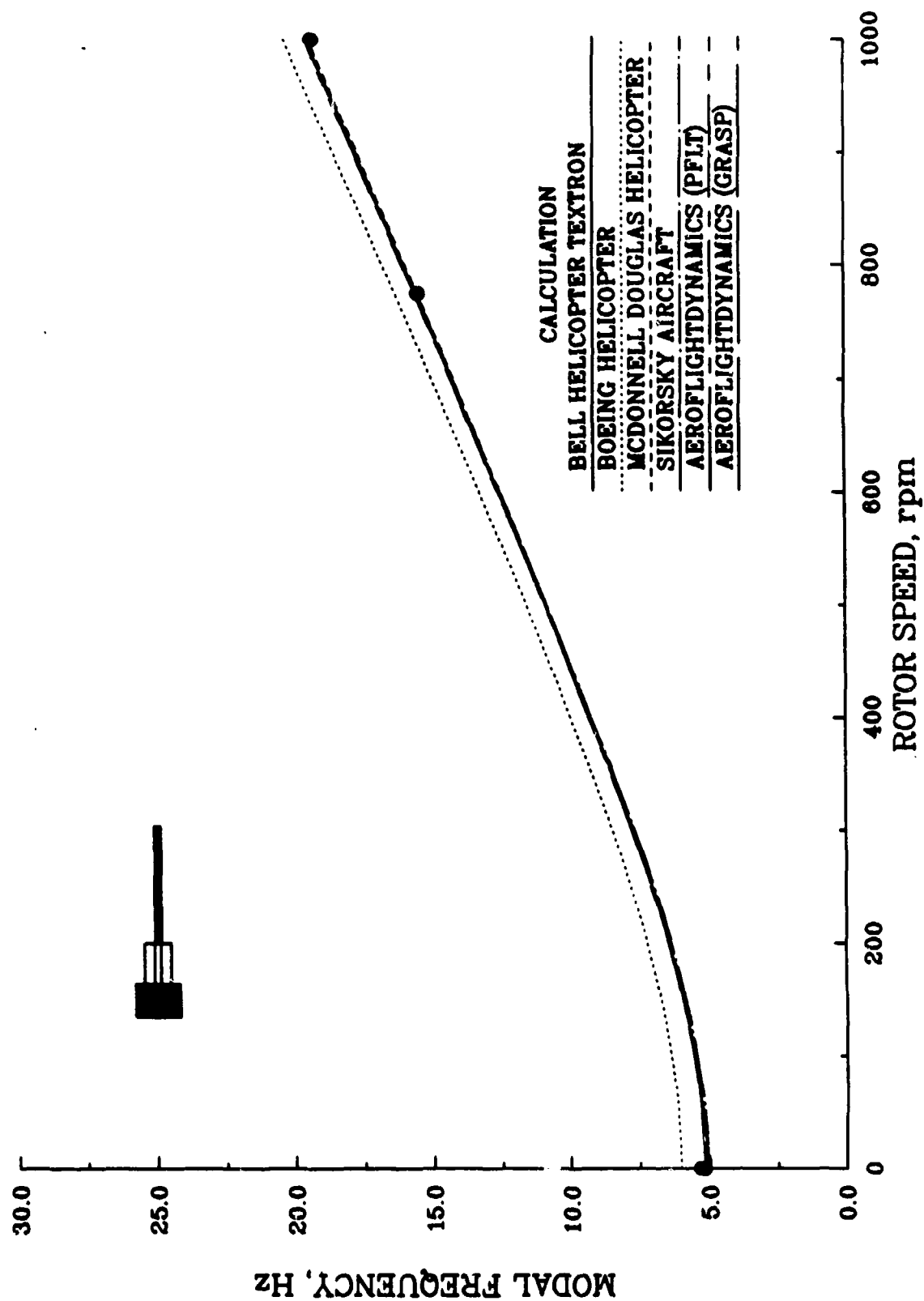
PITCH ANGLE = 8 deg



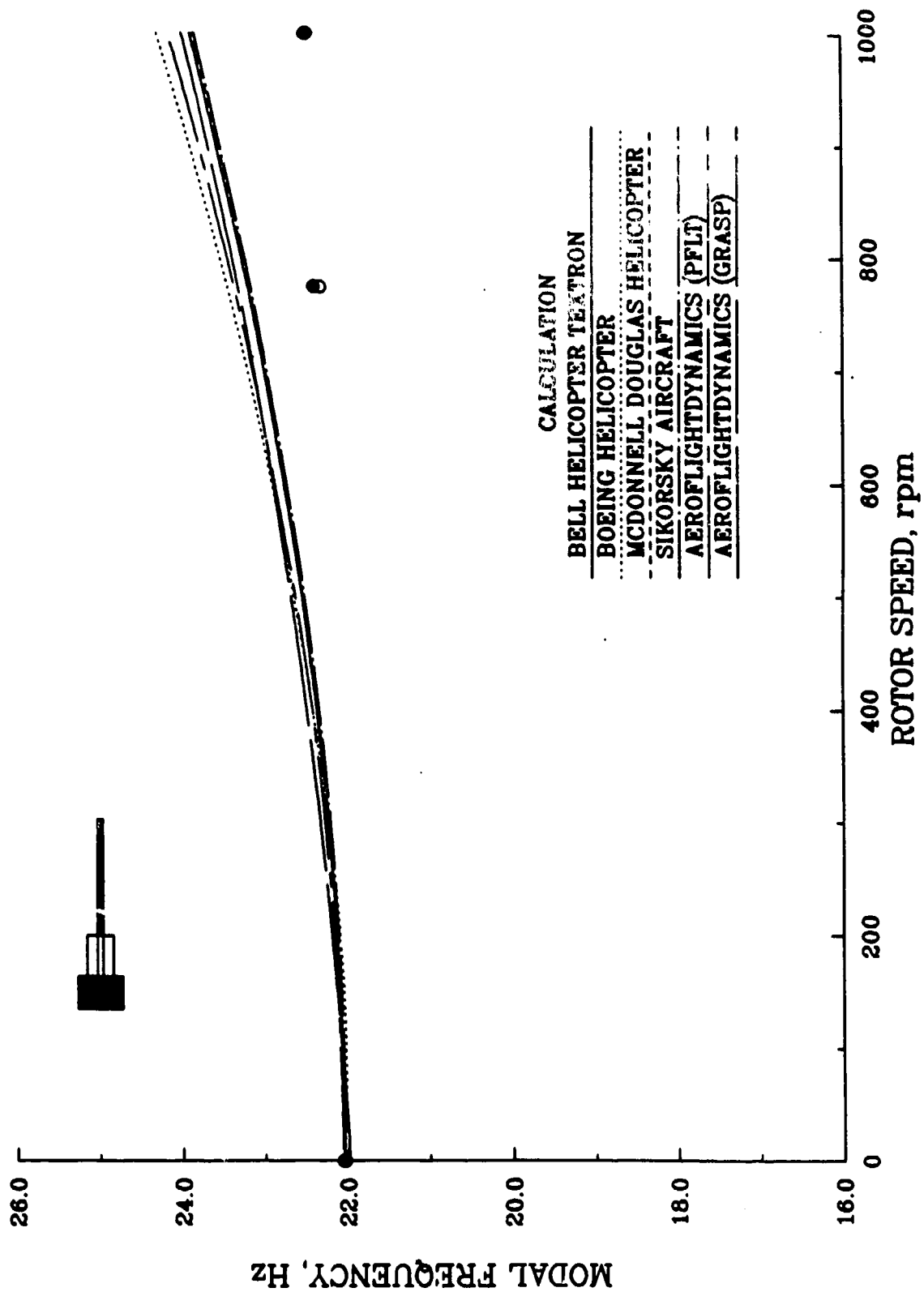
BLADE TIP DEFLECTION - TASK 86g  
 LINEAR AERODYNAMIC COEFFICIENTS  
 CASE 6 - TORSIONALLY SOFT ROTOR  
 PITCH ANGLE = 12 deg



1st FLAP MODE FREQUENCY IN A VACUUM - TASK 86b  
CASE 2 - TORSIONALLY SOFT ROTOR

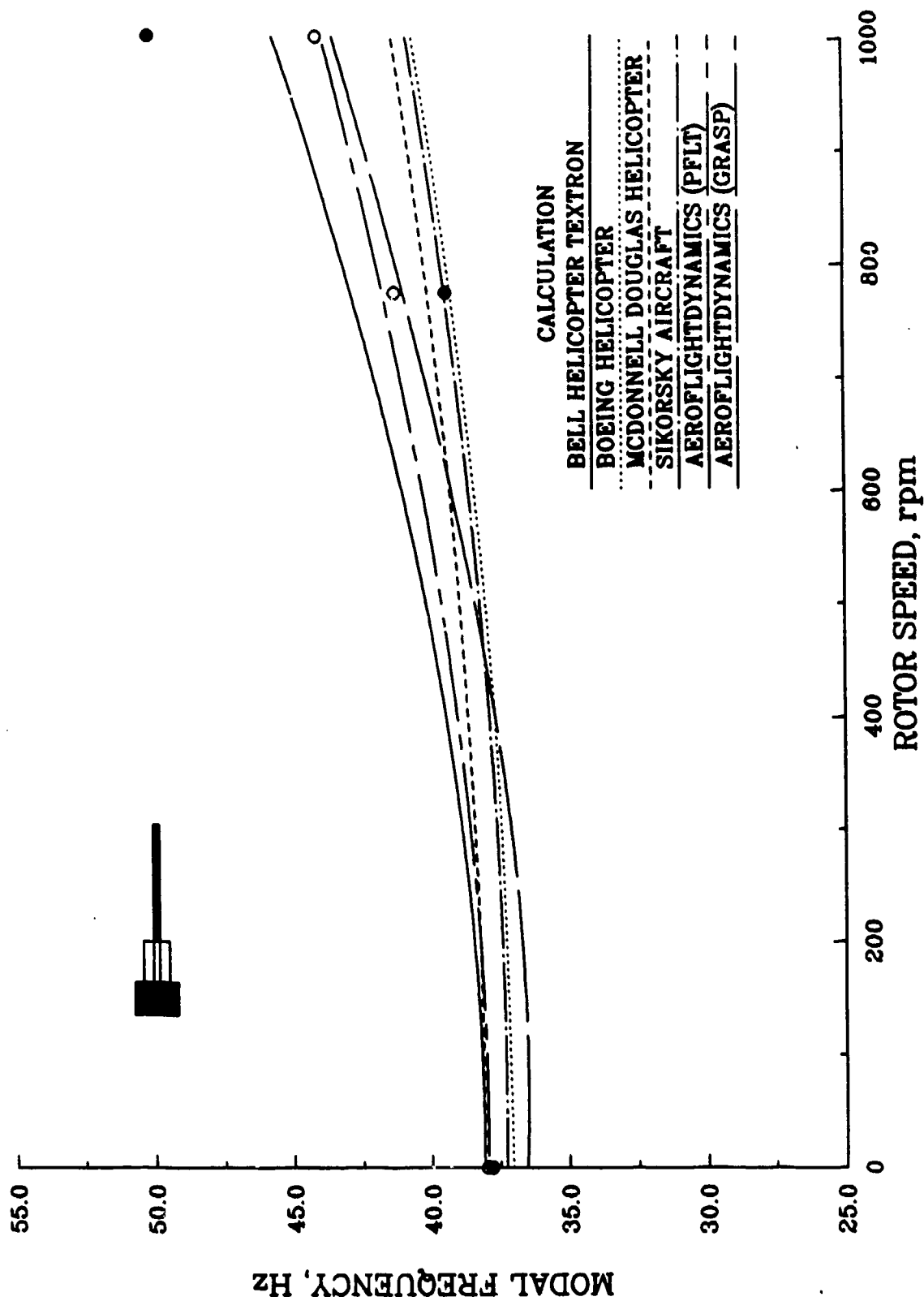


# 1st LEAD-LAG MODE FREQUENCY IN A VACUUM - TASK 86b CASE 2 - TORSIONALLY SOFT ROTOR

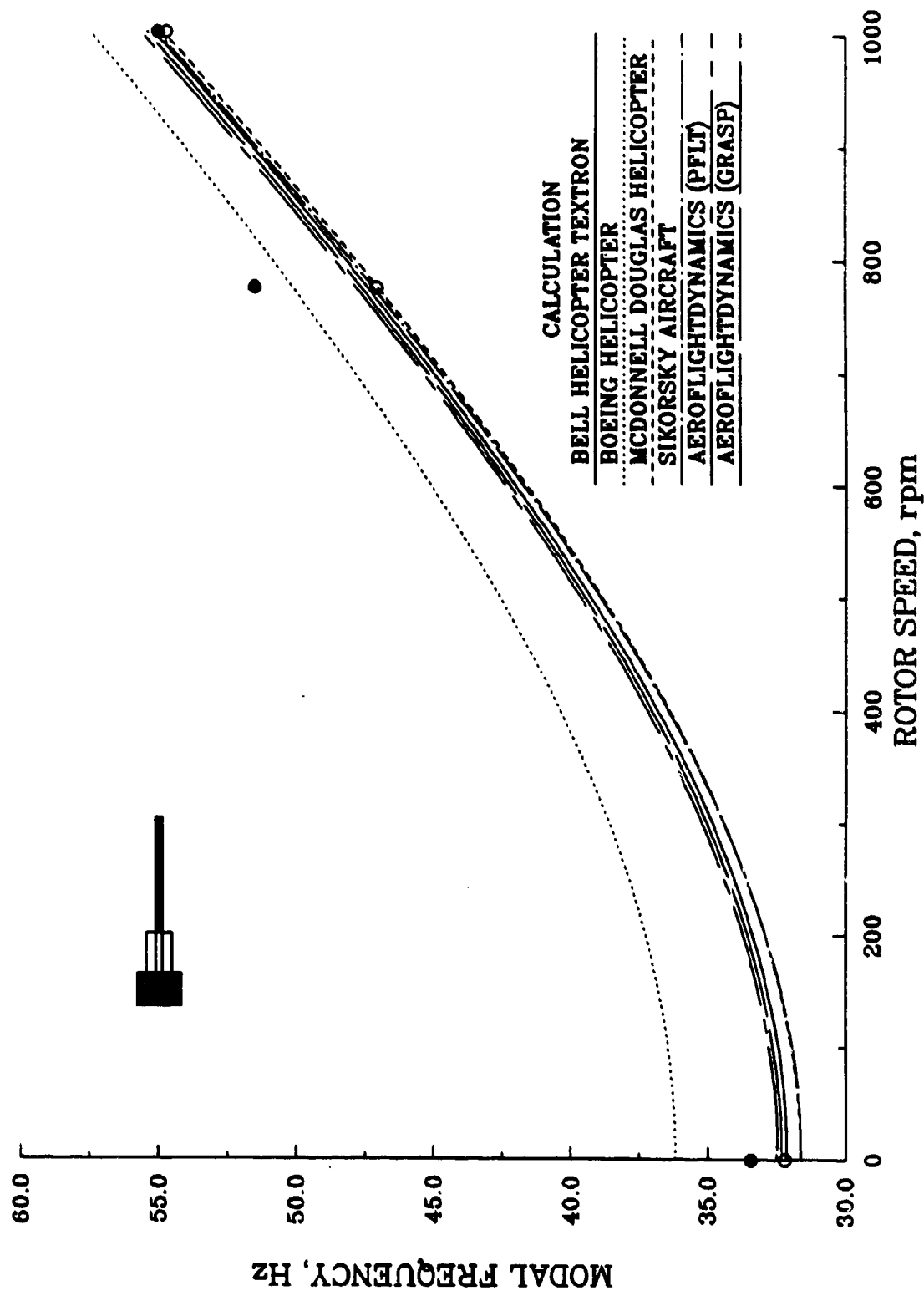




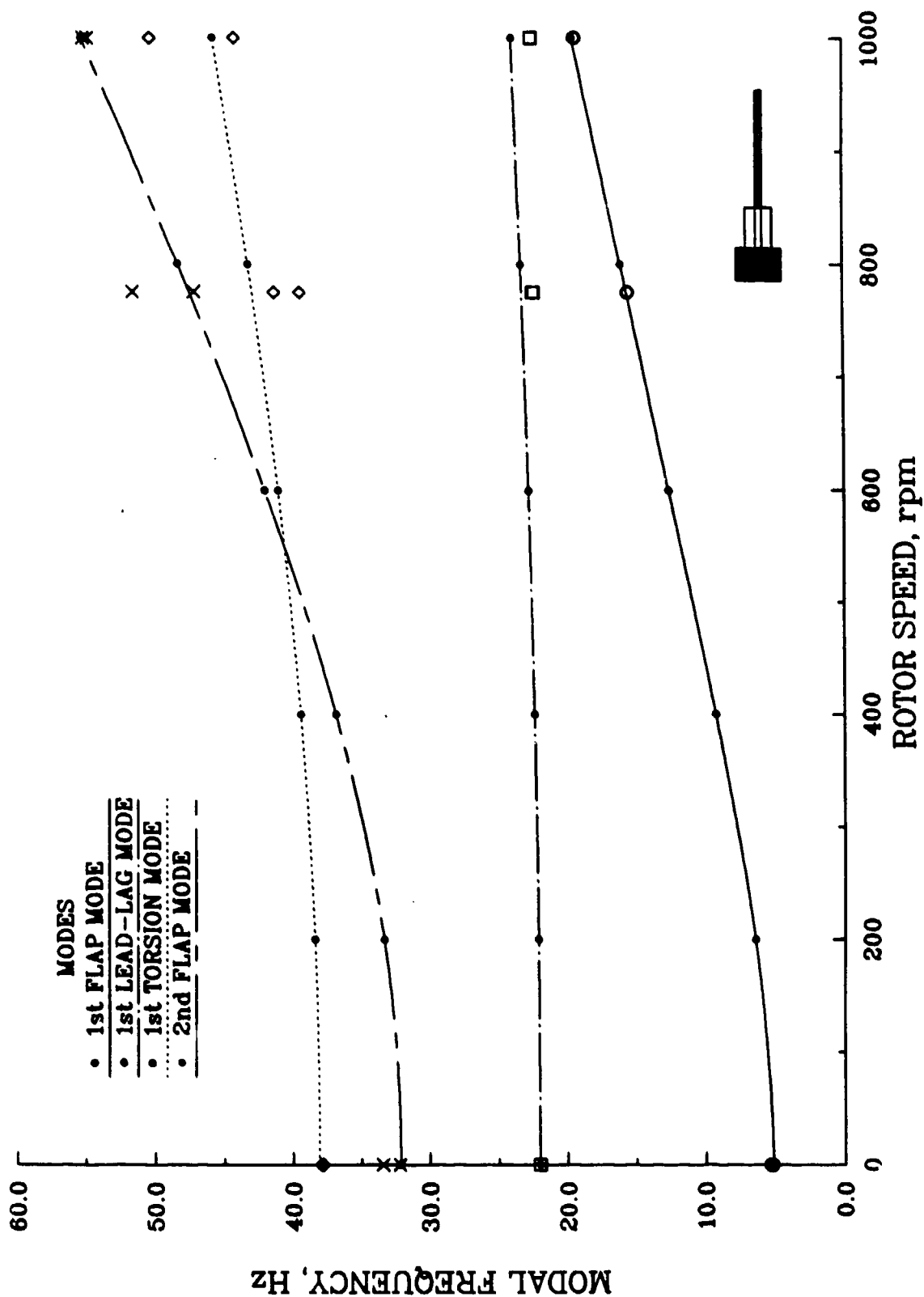
# 1st TORSION MODE FREQUENCY IN A VACUUM - TASK 86b CASE 2 - TORSIONALLY SOFT ROTOR



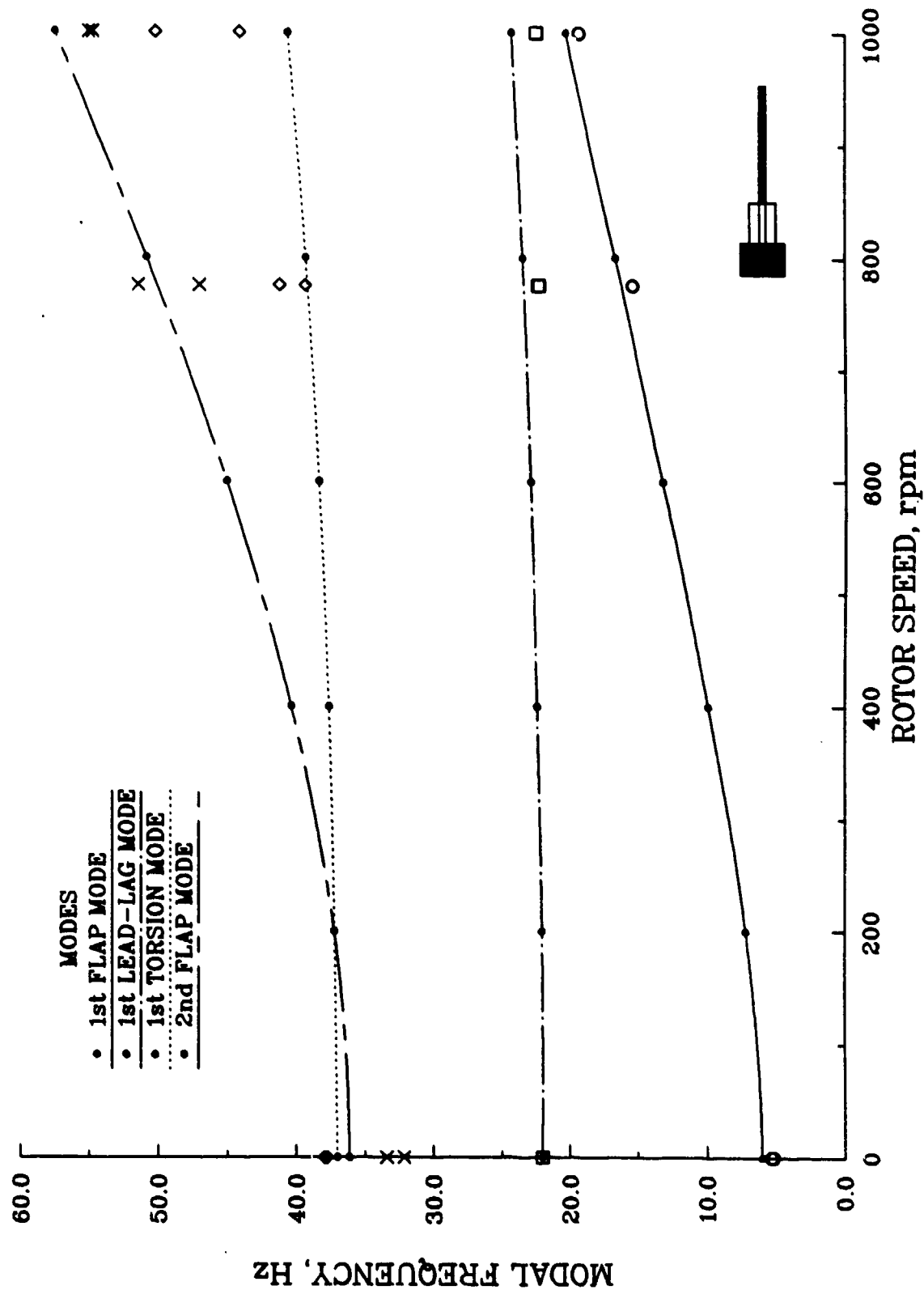
# 2nd FLAP MODE FREQUENCY IN A VACUUM - TASK 86b CASE 2 - TORSIONALLY SOFT ROTOR



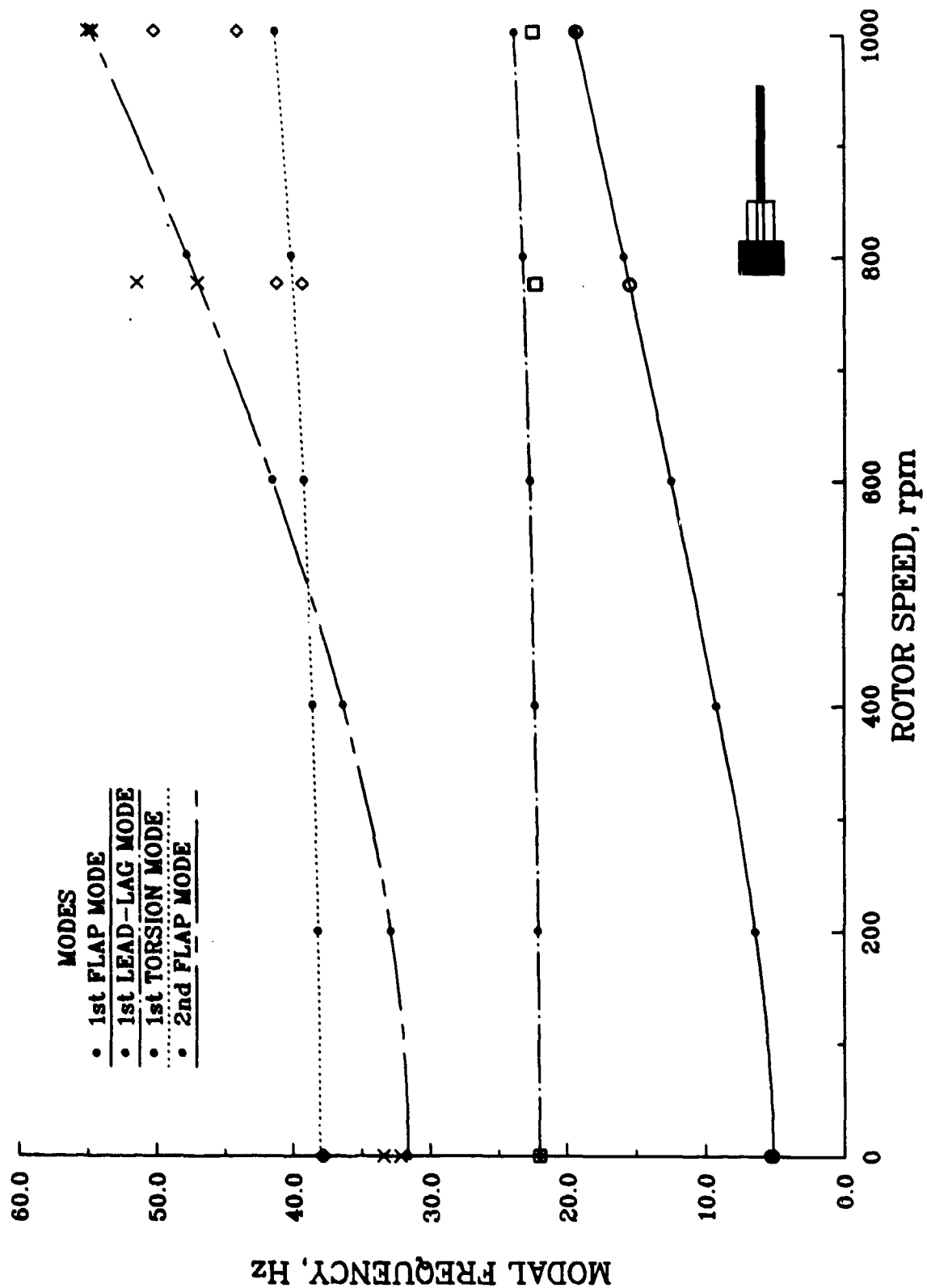
MODAL FREQUENCIES IN A VACUUM - TASK 86b  
CASE 2 - TORSIONALLY SOFT ROTOR  
BELL HELICOPTER TEXTRON



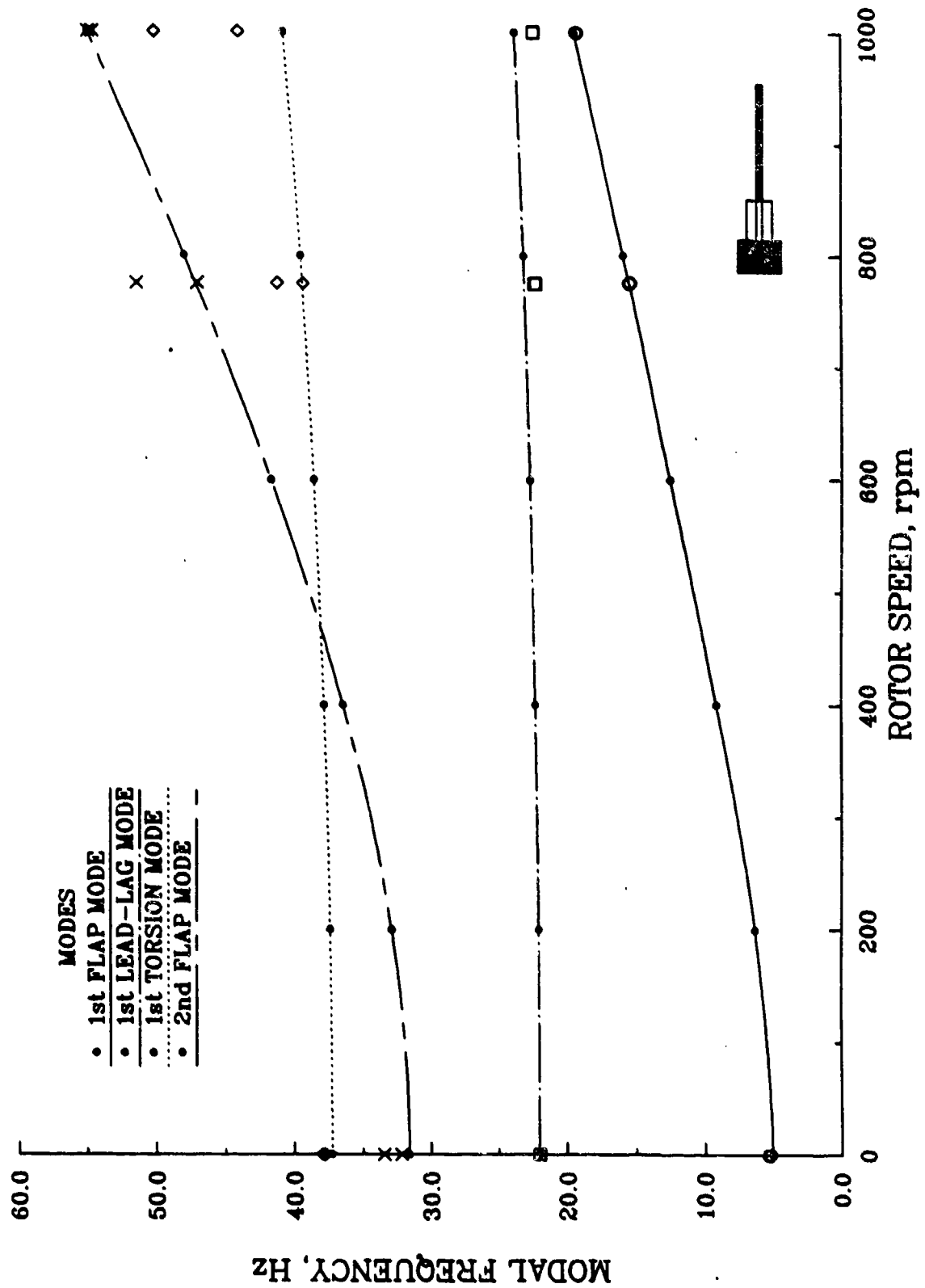
# MODAL FREQUENCIES IN A VACUUM - TASK 86b CASE 2 - TORSIONALLY SOFT ROTOR BOEING HELICOPTER



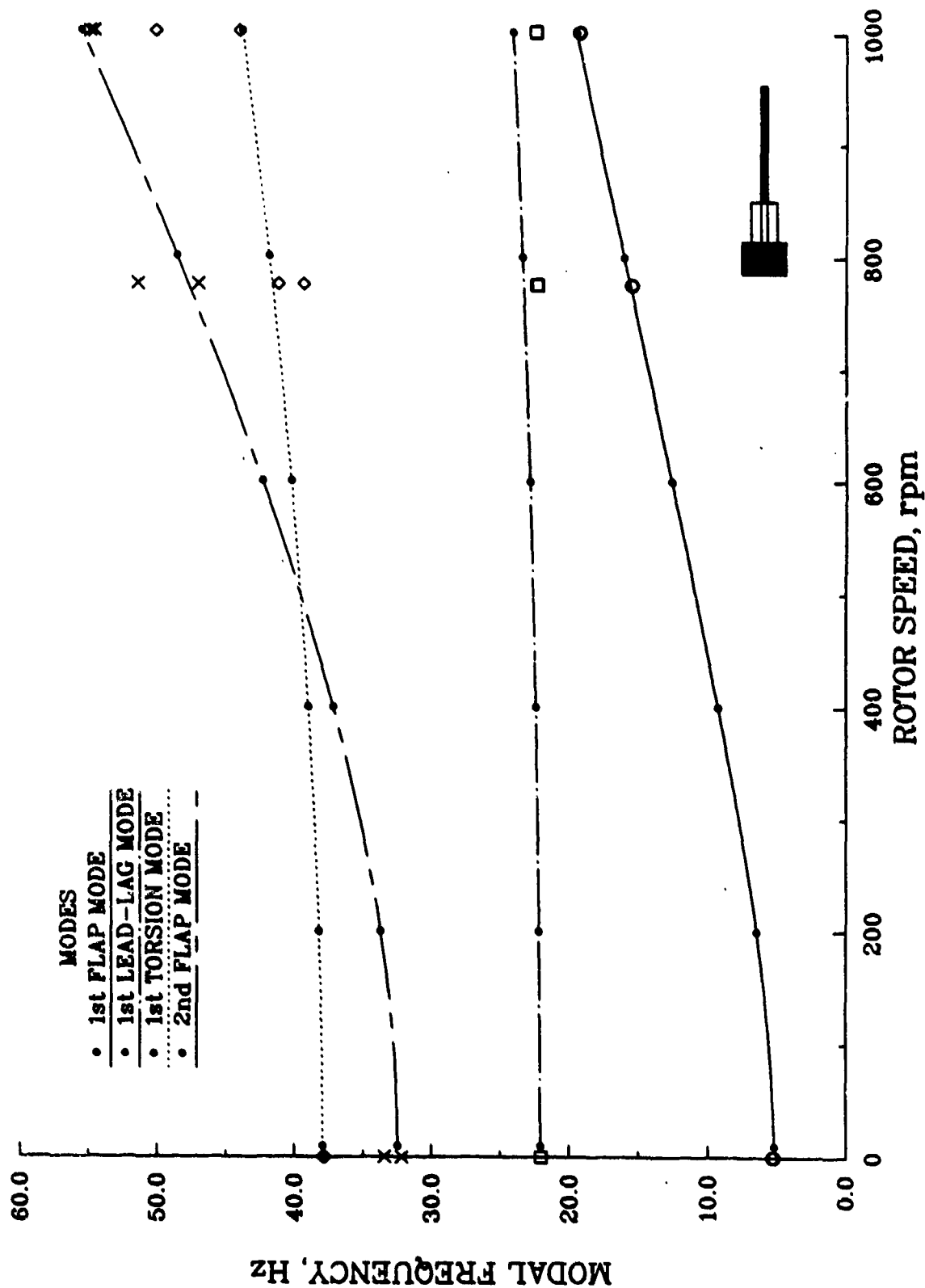
MODAL FREQUENCIES IN A VACUUM - TASK 86b  
CASE 2 - TORSIONALLY SOFT ROTOR  
MCDONNELL DOUGLAS HELICOPTER



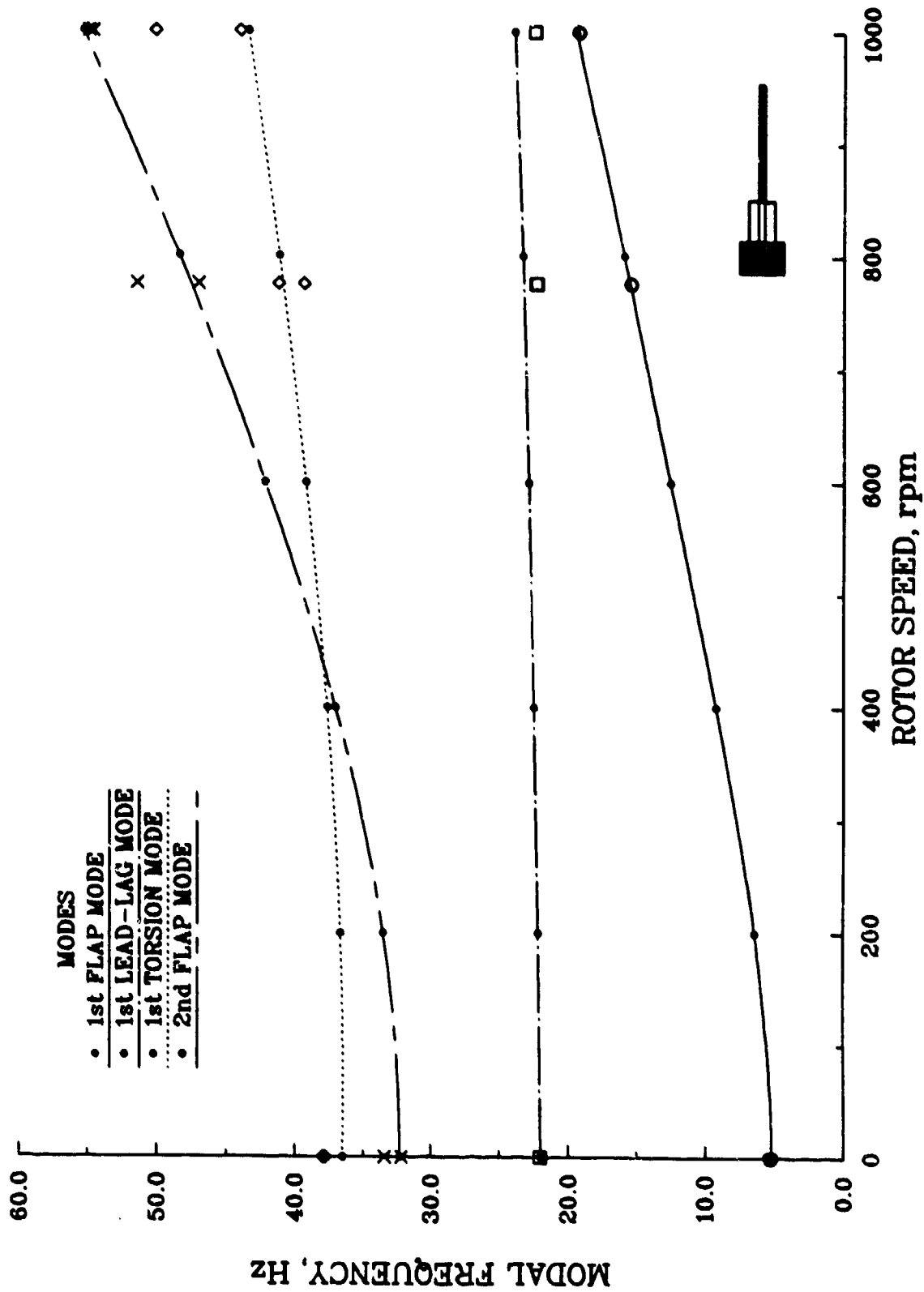
# MODAL FREQUENCIES IN A VACUUM - TASK 86b CASE 2 - TORSIONALLY SOFT ROTOR SIKORSKY AIRCRAFT



# MODAL FREQUENCIES IN A VACUUM - TASK 86b CASE 2 - TORSIONALLY SOFT ROTOR AEROFLIGHTDYNAMICS (PFLT)

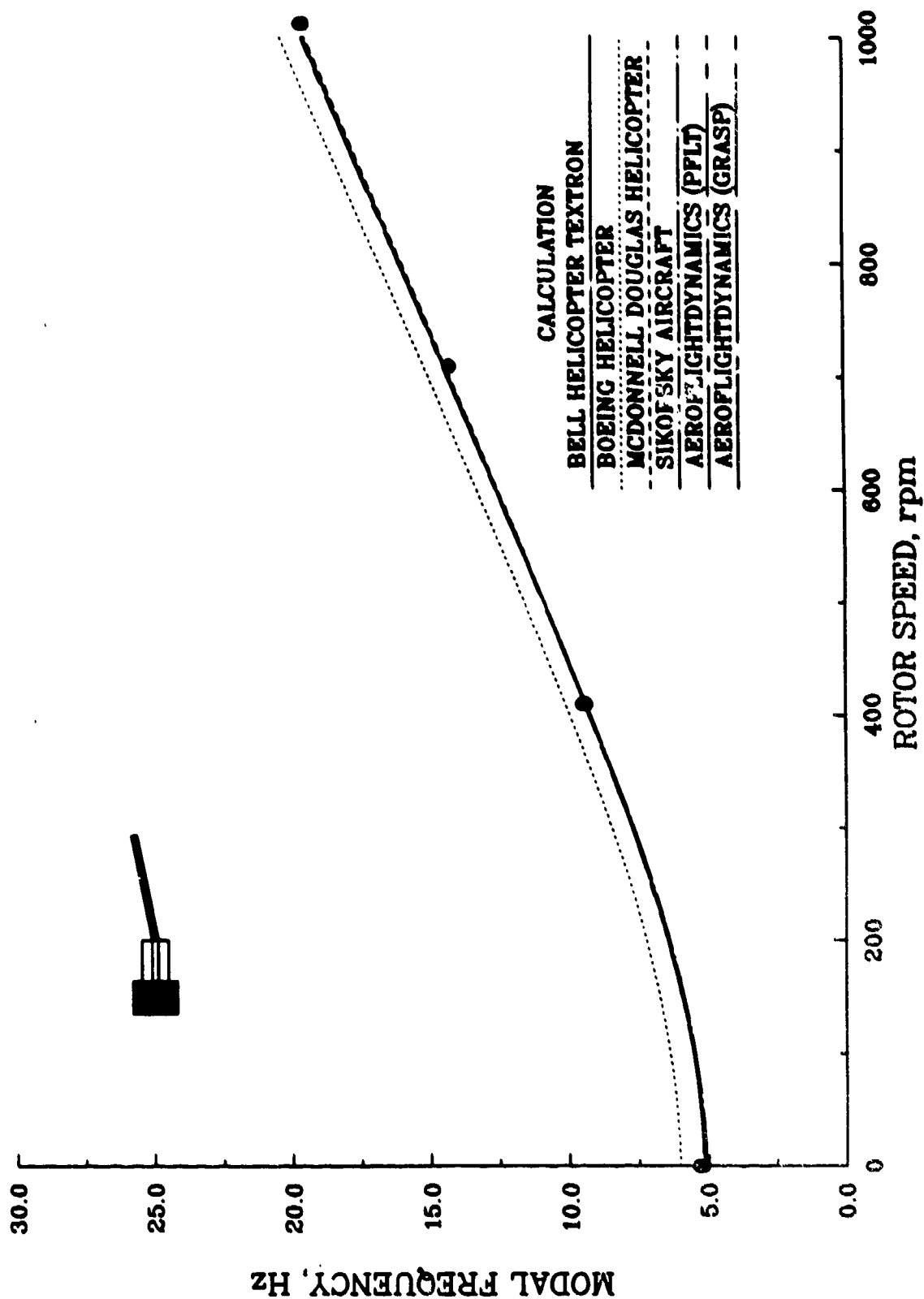


# MODAL FREQUENCIES IN A VACUUM - TASK 86b CASE 2 - TORSIONALLY SOFT ROTOR AEROFLIGHTDYNAMICS (GRASP)

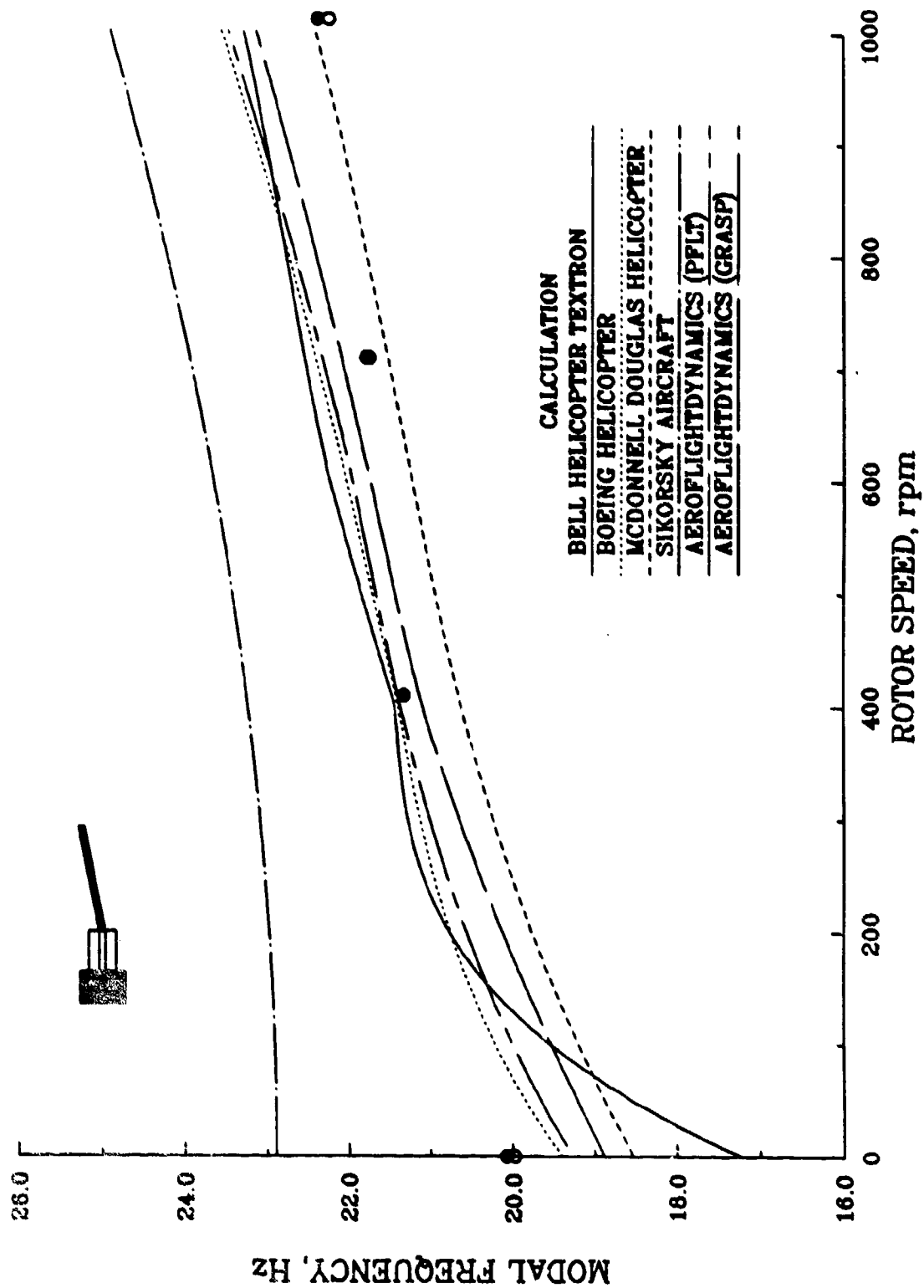




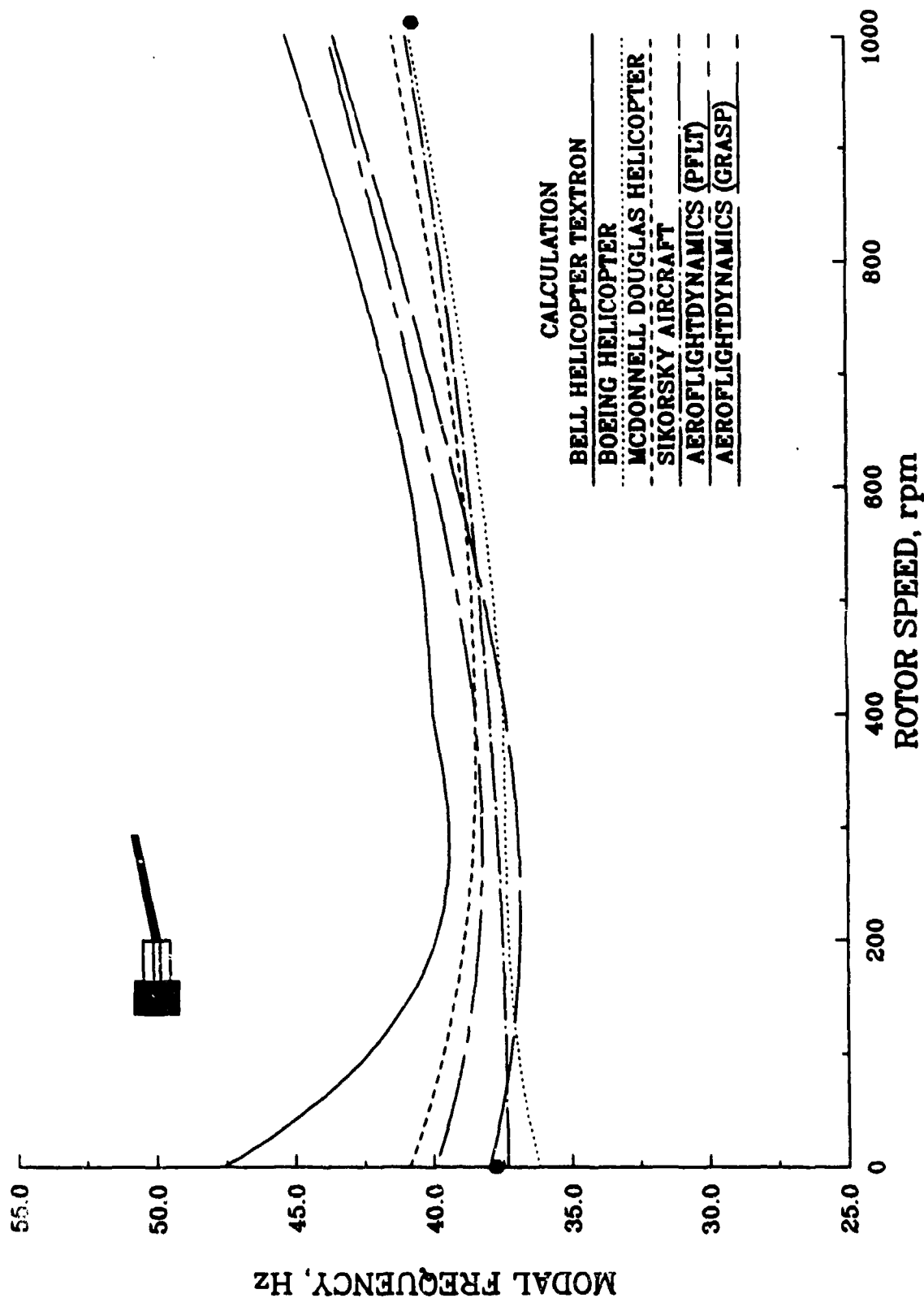
# 1st FLAP MODE FREQUENCY IN A VACUUM -- TASK 86c CASE 6 -- TORSIONALLY SOFT ROTOR



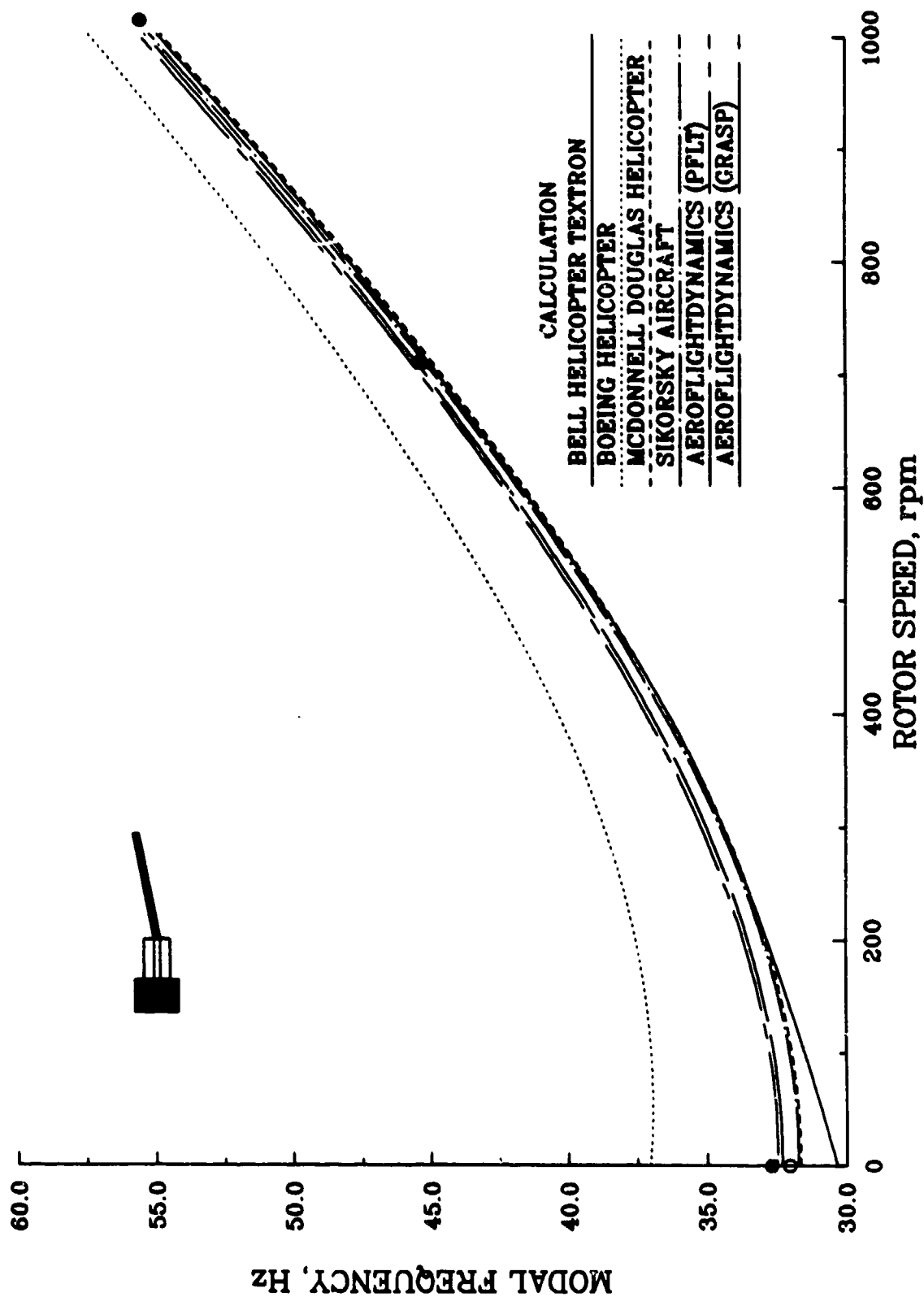
# 1st LEAD-LAG MODE FREQUENCY IN A VACUUM - TASK 86c CASE 6 - TORSIONALLY SOFT ROTOR



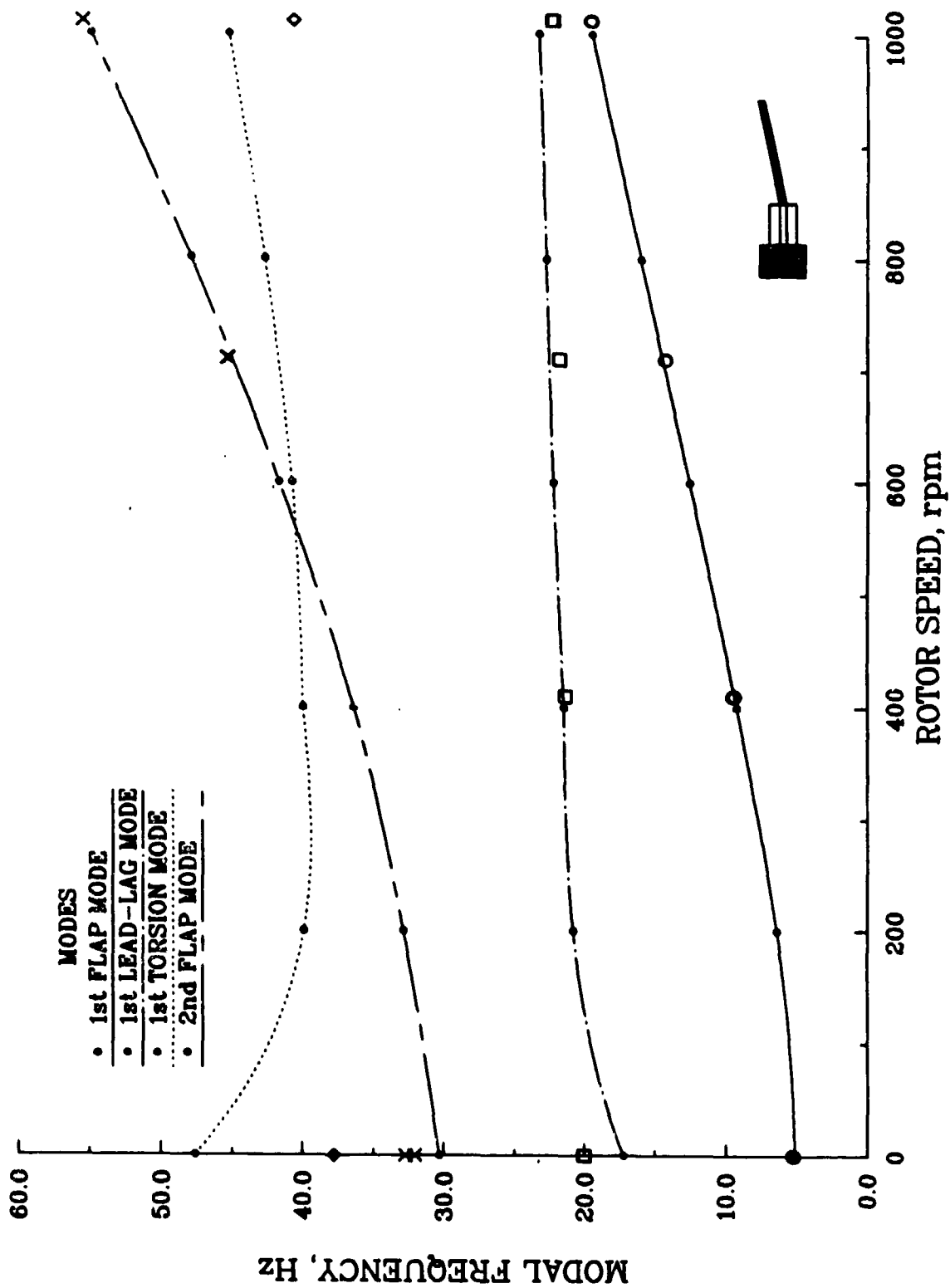
# 1st TORSION MODE FREQUENCY IN A VACUUM - TASK 86c CASE 6 - TORSIONALLY SOFT ROTOR



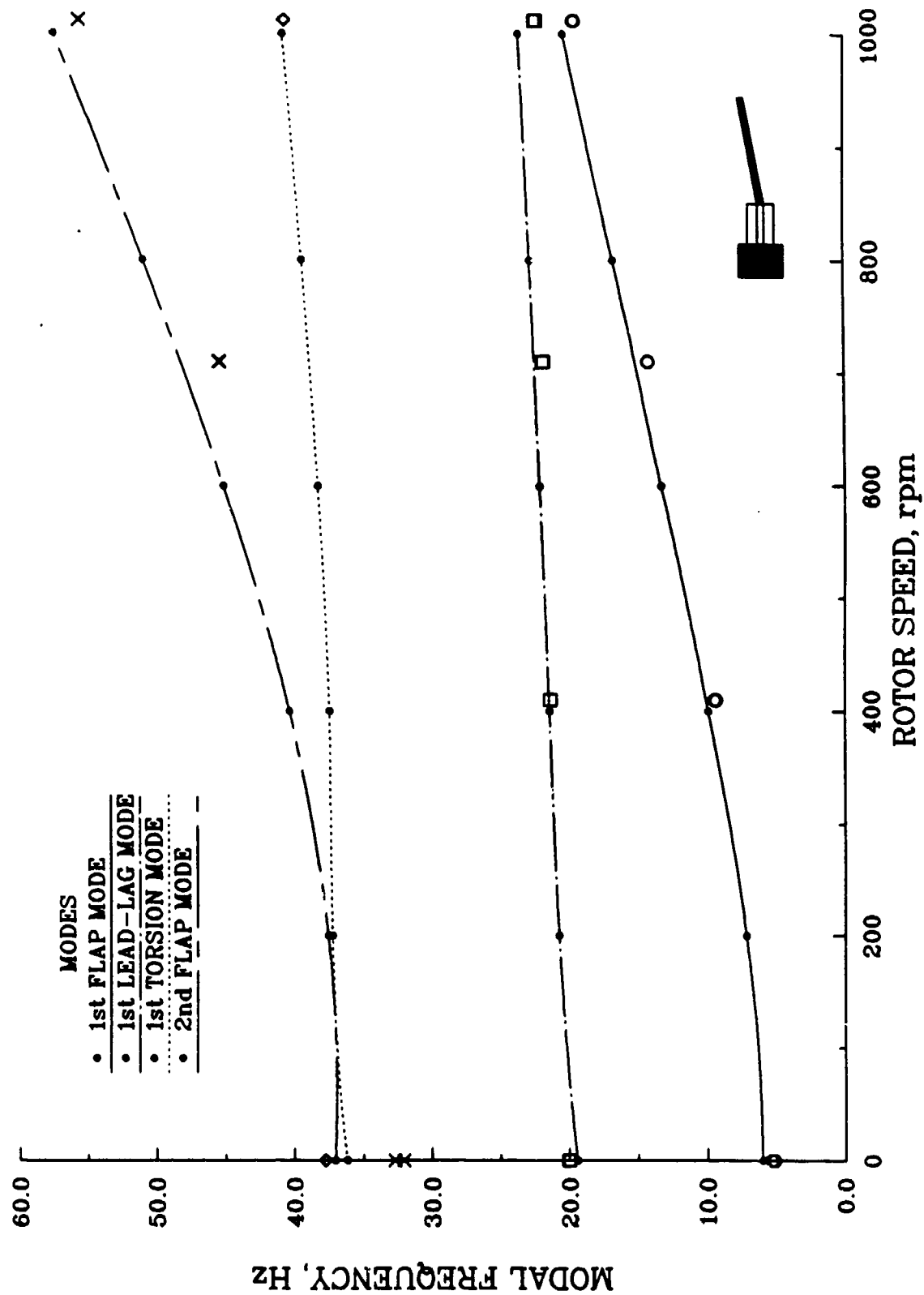
# 2nd FLAP MODE FREQUENCY IN A VACUUM - TASK 86c CASE 6 - TORSIONALLY SOFT ROTOR



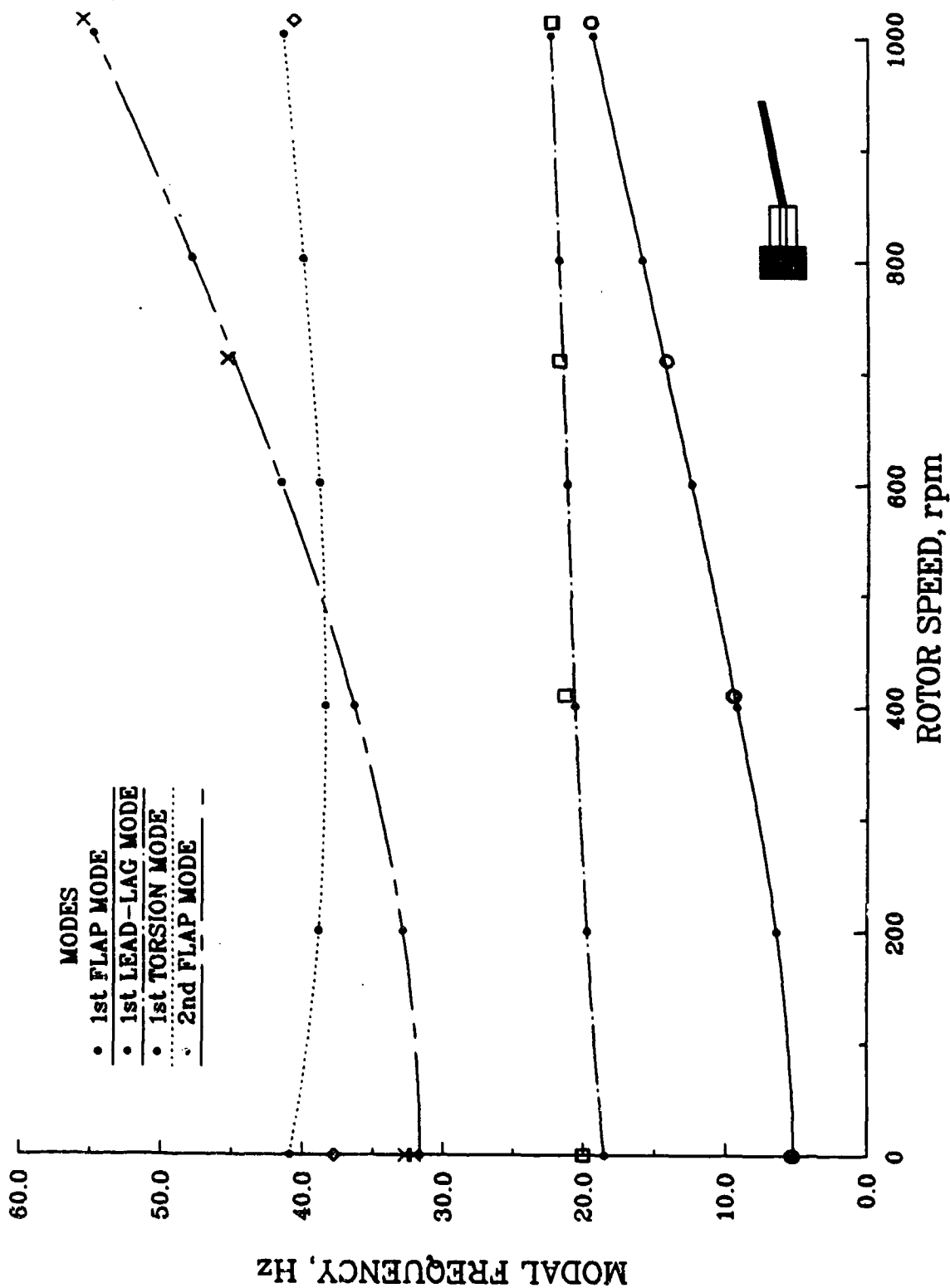
MODAL FREQUENCIES IN A VACUUM - TASK 86c  
CASE 6 - TORSIONALLY SOFT ROTOR  
BELL HELICOPTER TEXTRON



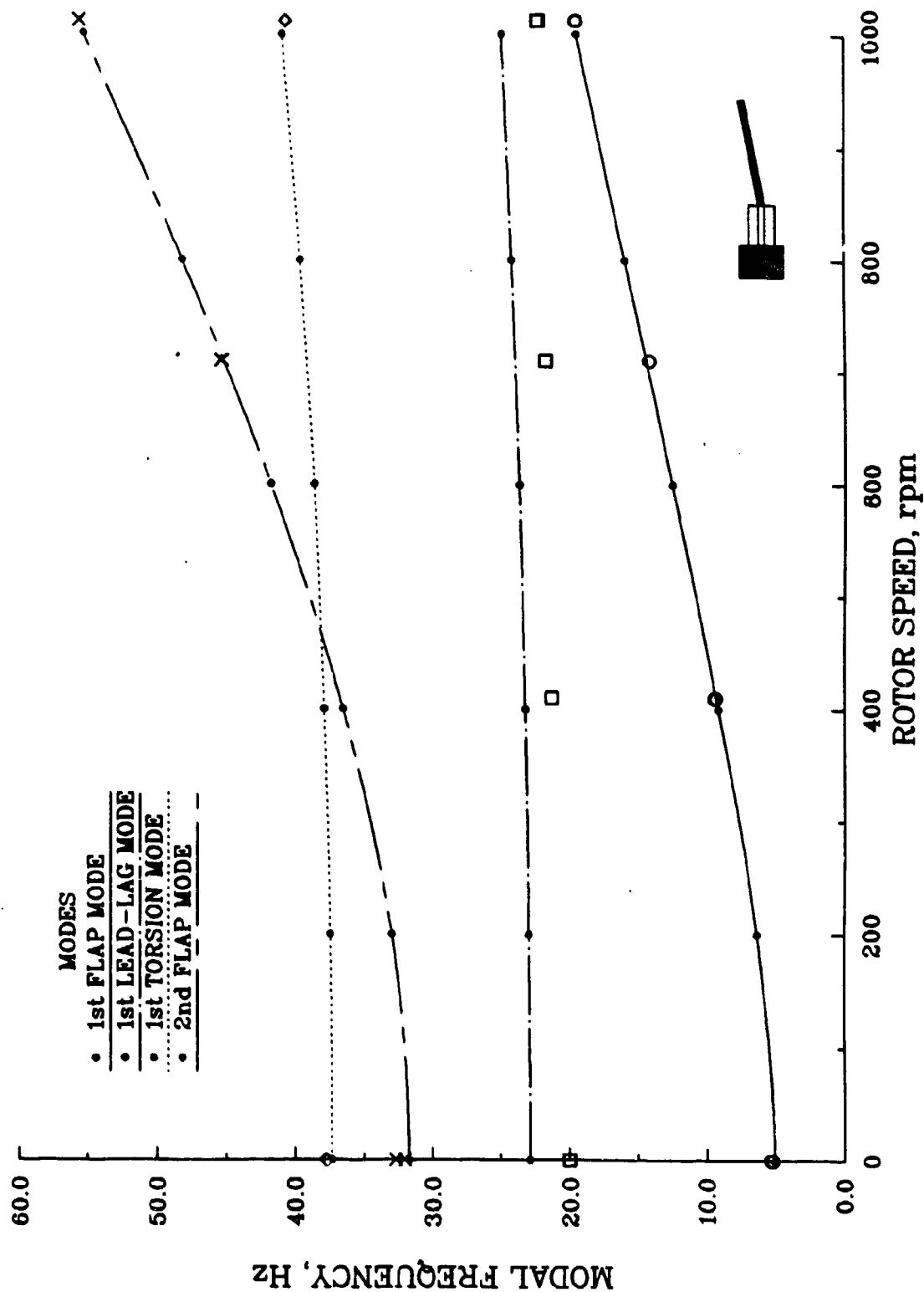
# MODAL FREQUENCIES IN A VACUUM - TASK 86c CASE 6 - TORSIONALLY SOFT ROTOR BOEING HELICOPTER



MODAL FREQUENCIES IN A VACUUM - TASK 86c  
CASE 6 - TORSIONALLY SOFT ROTOR  
MCDONNELL DOUGLAS HELICOPTER

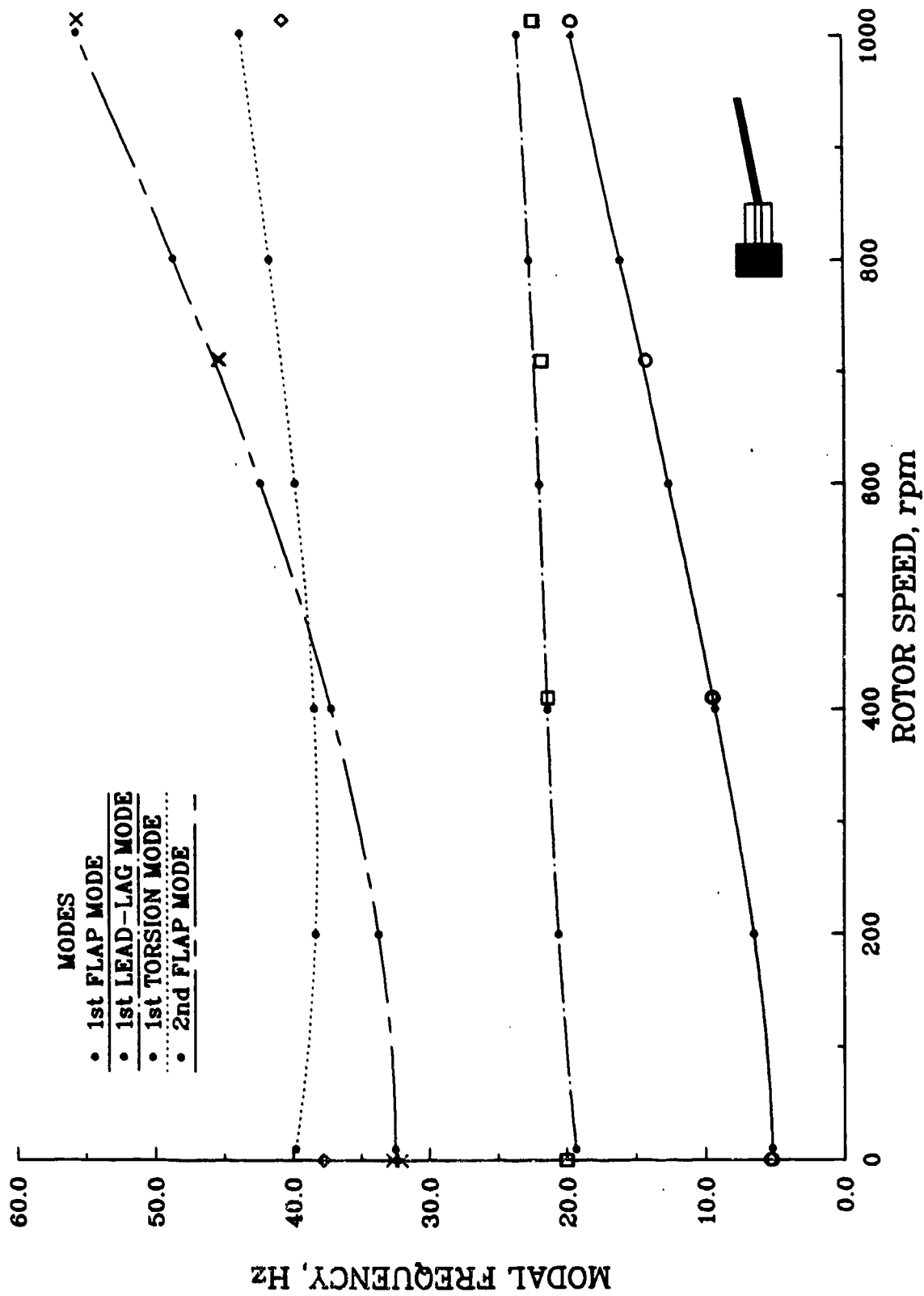


MODAL FREQUENCIES IN A VACUUM - TASK 86c  
CASE 6 - TORSIONALLY SOFT ROTOR  
SIKORSKY AIRCRAFT

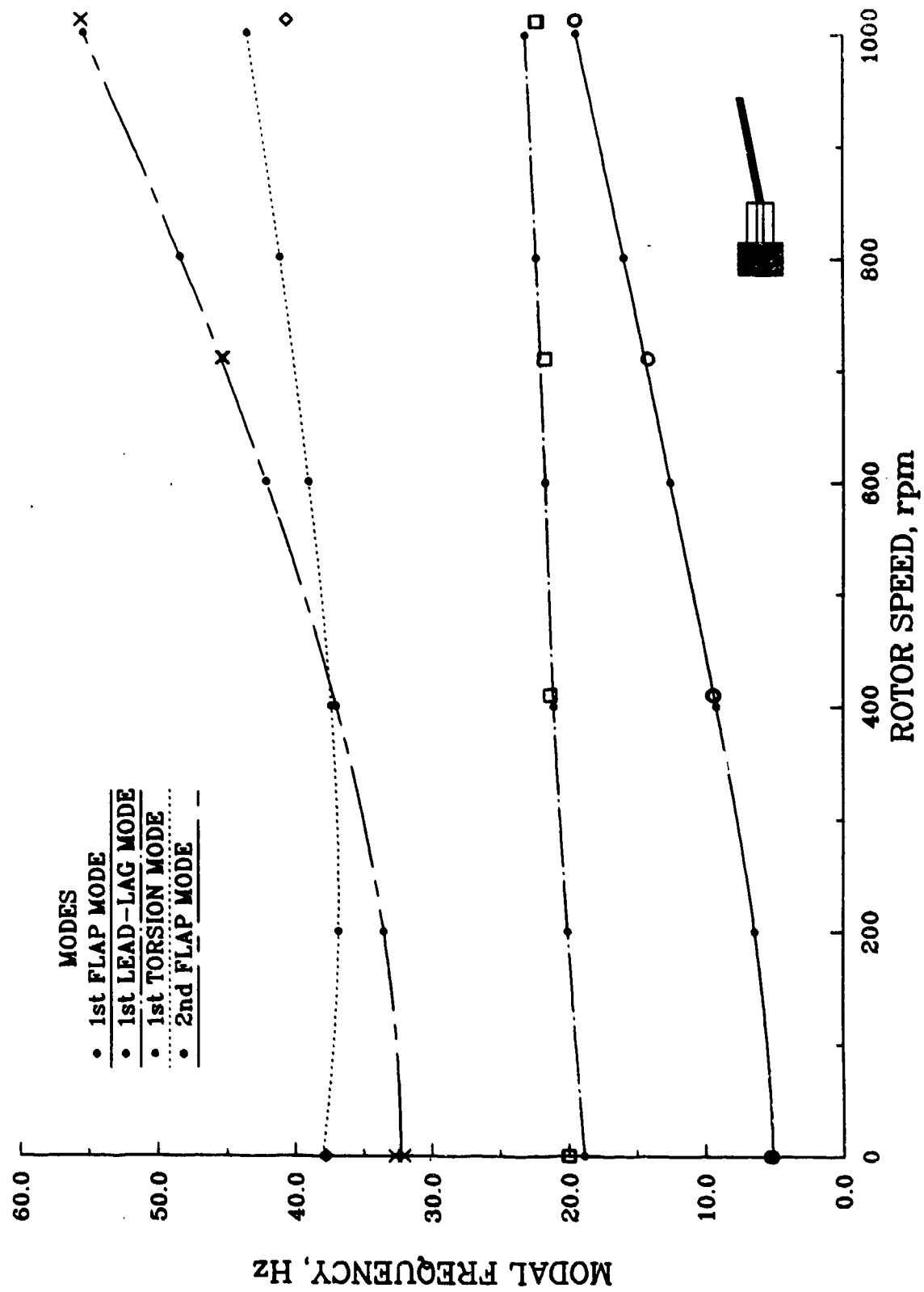




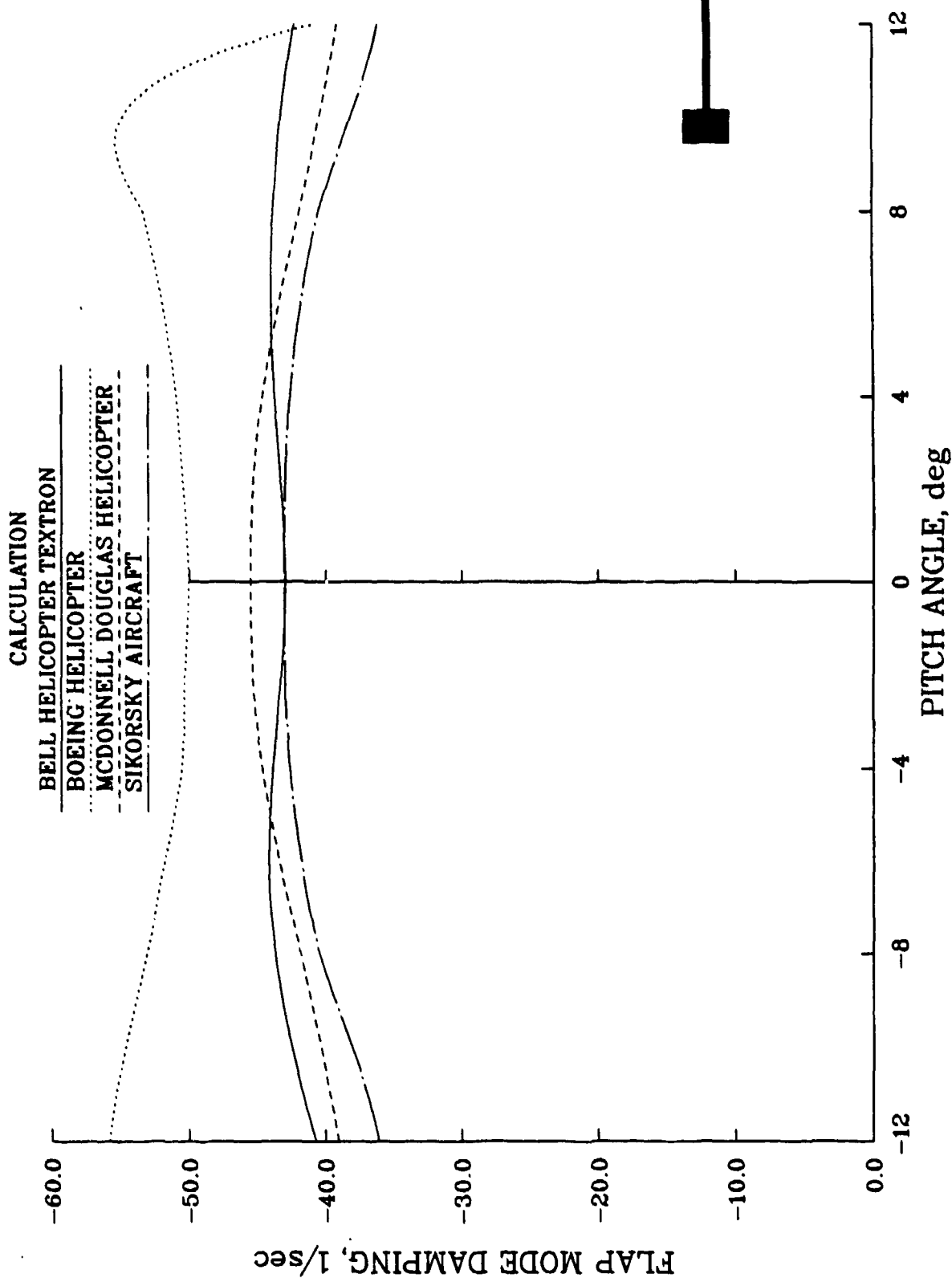
# MODAL FREQUENCIES IN A VACUUM - TASK 86c CASE 6 - TORSIONALLY SOFT ROTOR AEROFLIGHTDYNAMICS (PFLT)



MODAL FREQUENCIES IN A VACUUM - TASK 86c  
CASE 6 - TORSIONALLY SOFT ROTOR  
AIRCRAFT DYNAMICS (GRASP)



# FLAP MODE DAMPING - TASK 86h SIMPLIFIED ROTOR WITHOUT PRECONE



# FLAP MODE FREQUENCY - TASK 86h SIMPLIFIED ROTOR WITHOUT PRECONE

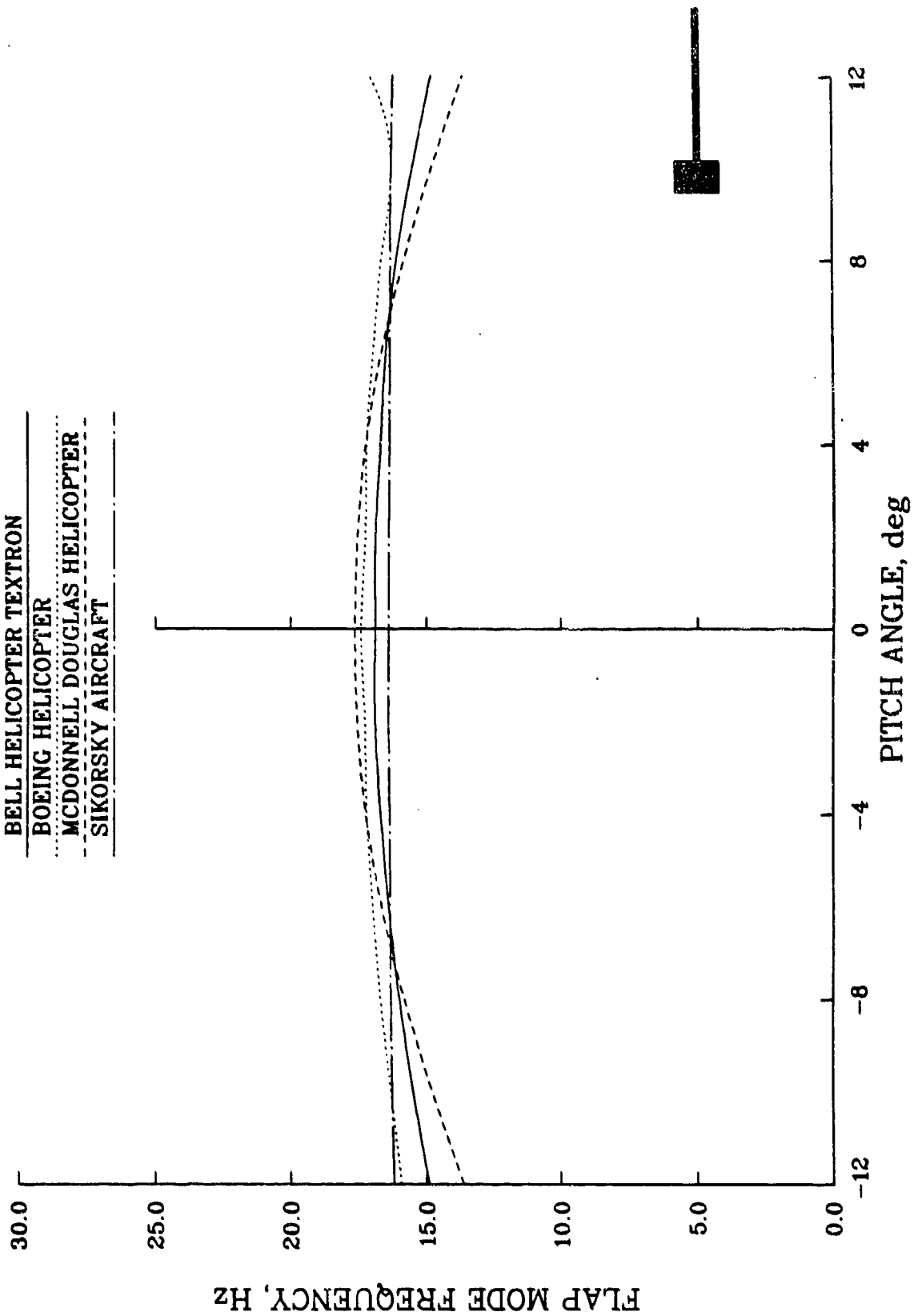
## CALCULATION

BELL HELICOPTER TEXTRON

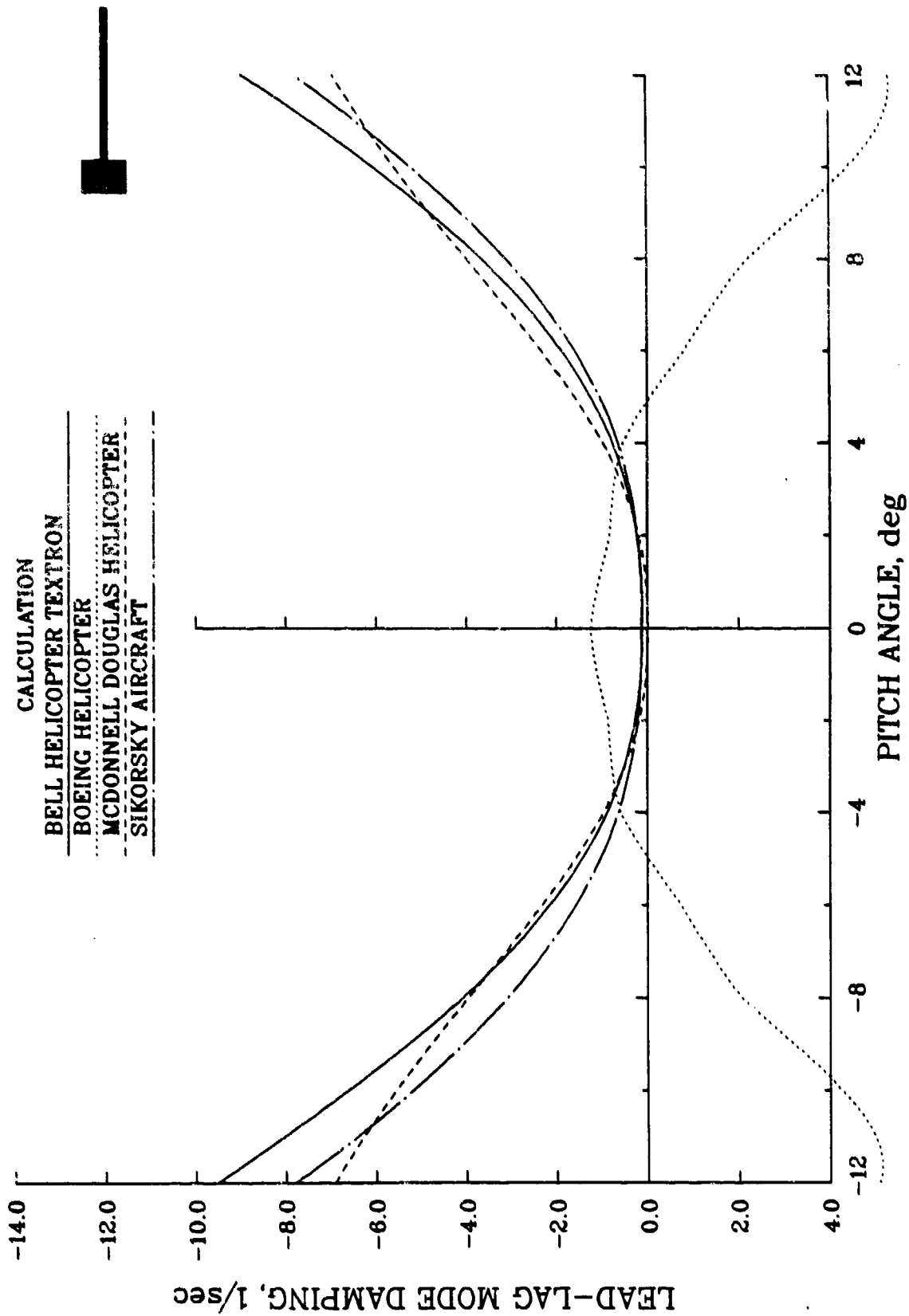
BOEING HELICOPTER

MCDONNELL DOUGLAS HELICOPTER

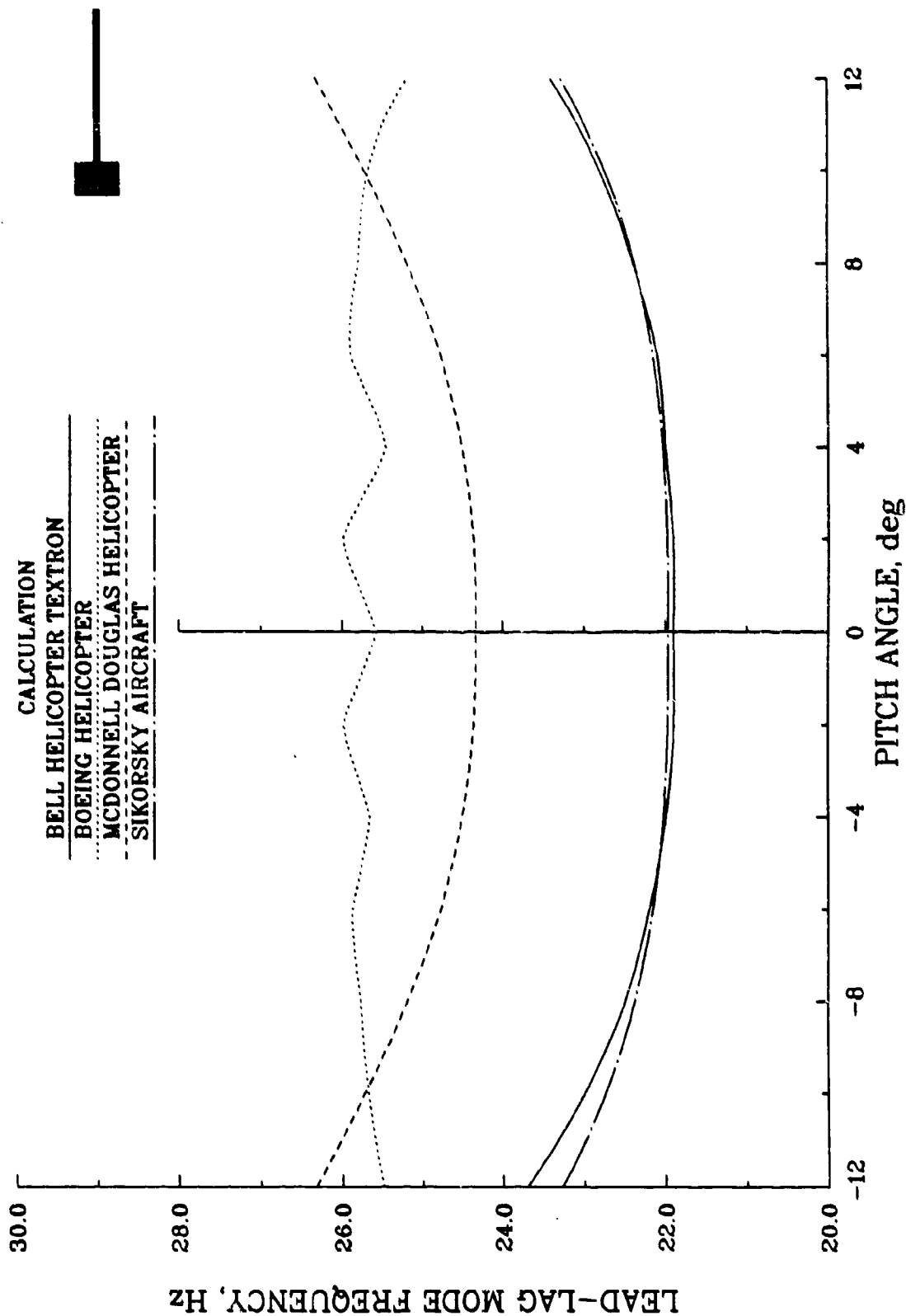
SIKORSKY AIRCRAFT



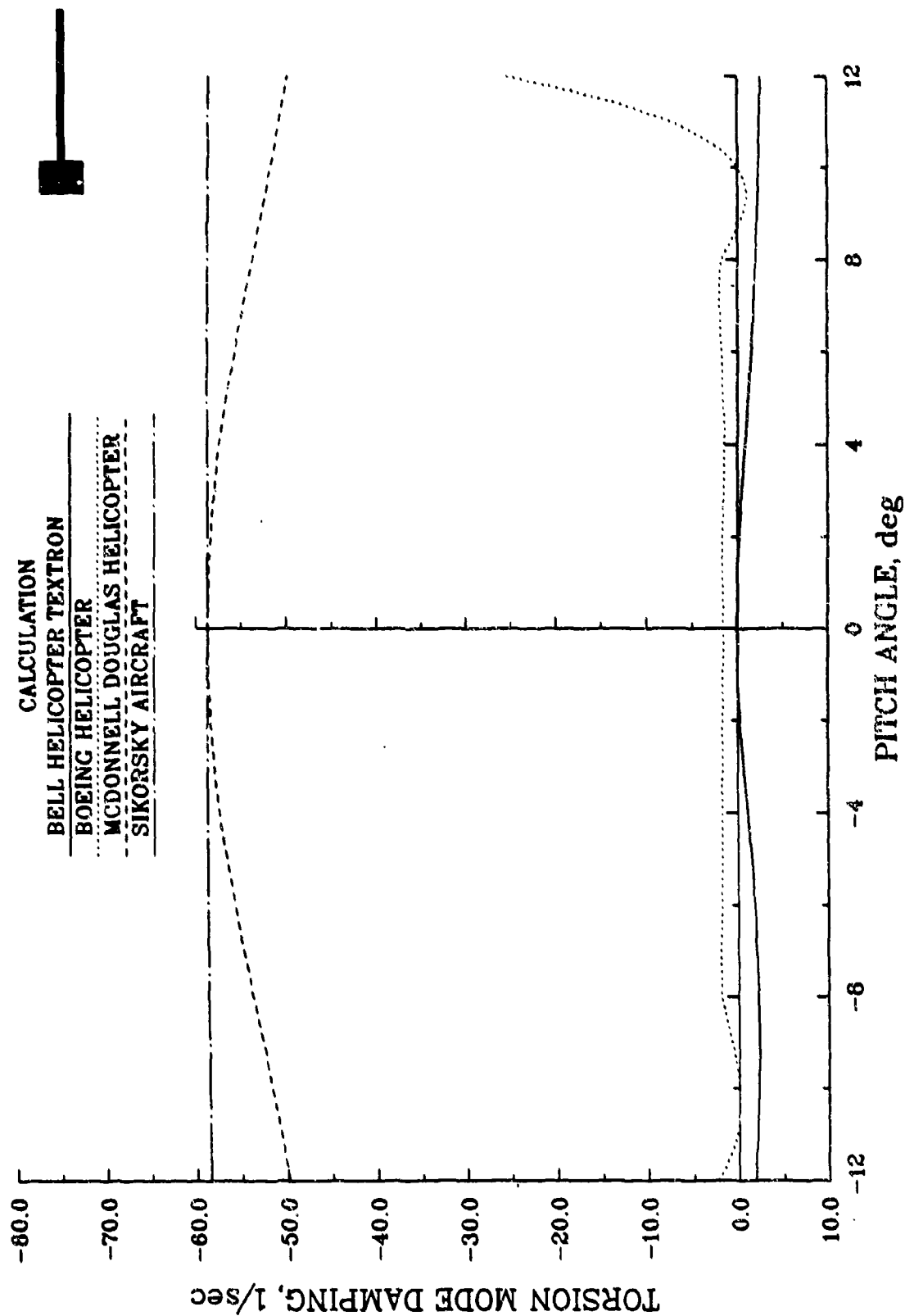
# LEAD-LAG MODE DAMPING - TASK 86h SIMPLIFIED ROTOR WITHOUT PRECONE



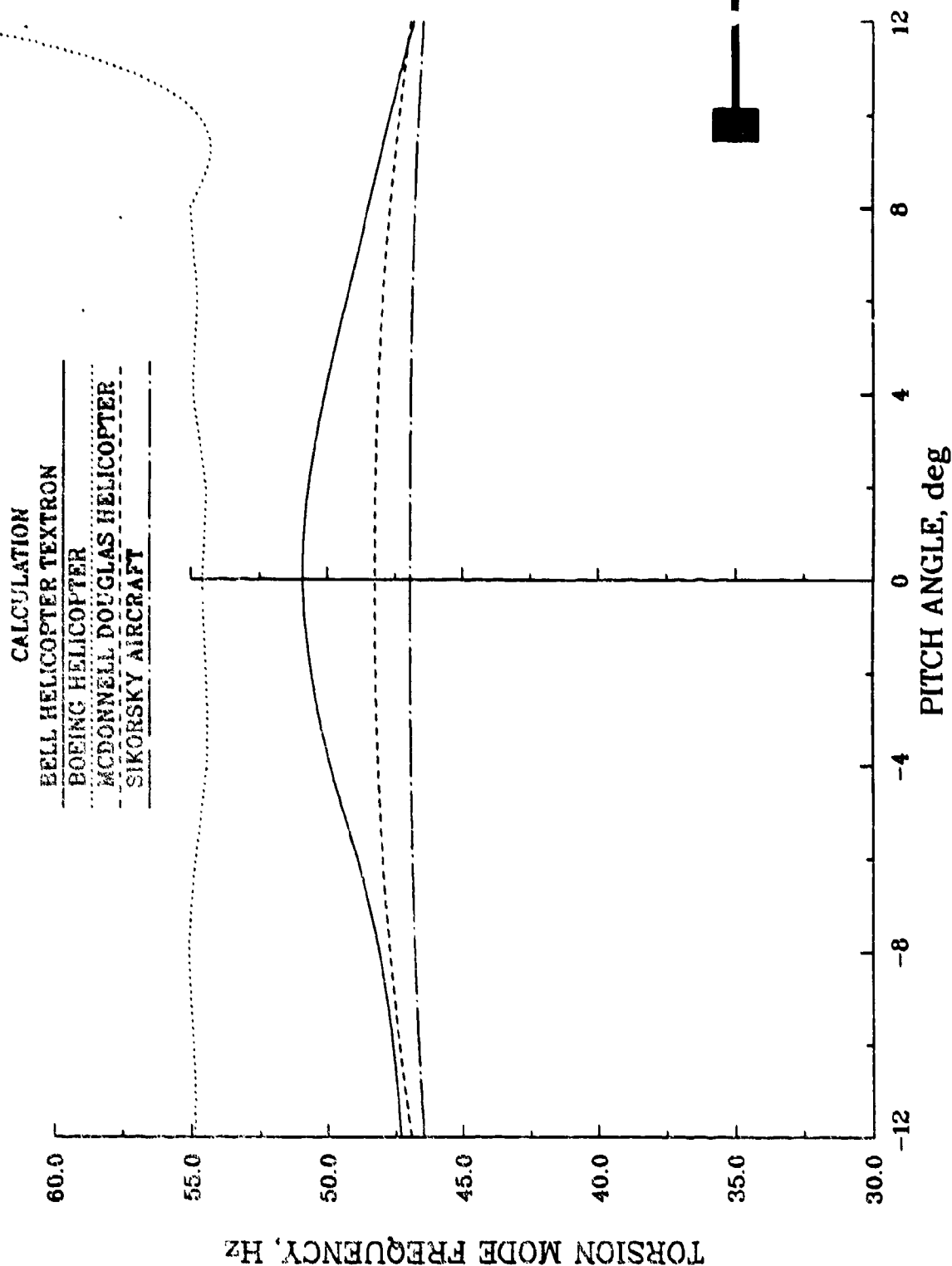
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# TORSION MODE DAMPING - TASK 86h SIMPLIFIED ROTOR WITHOUT PRECONE

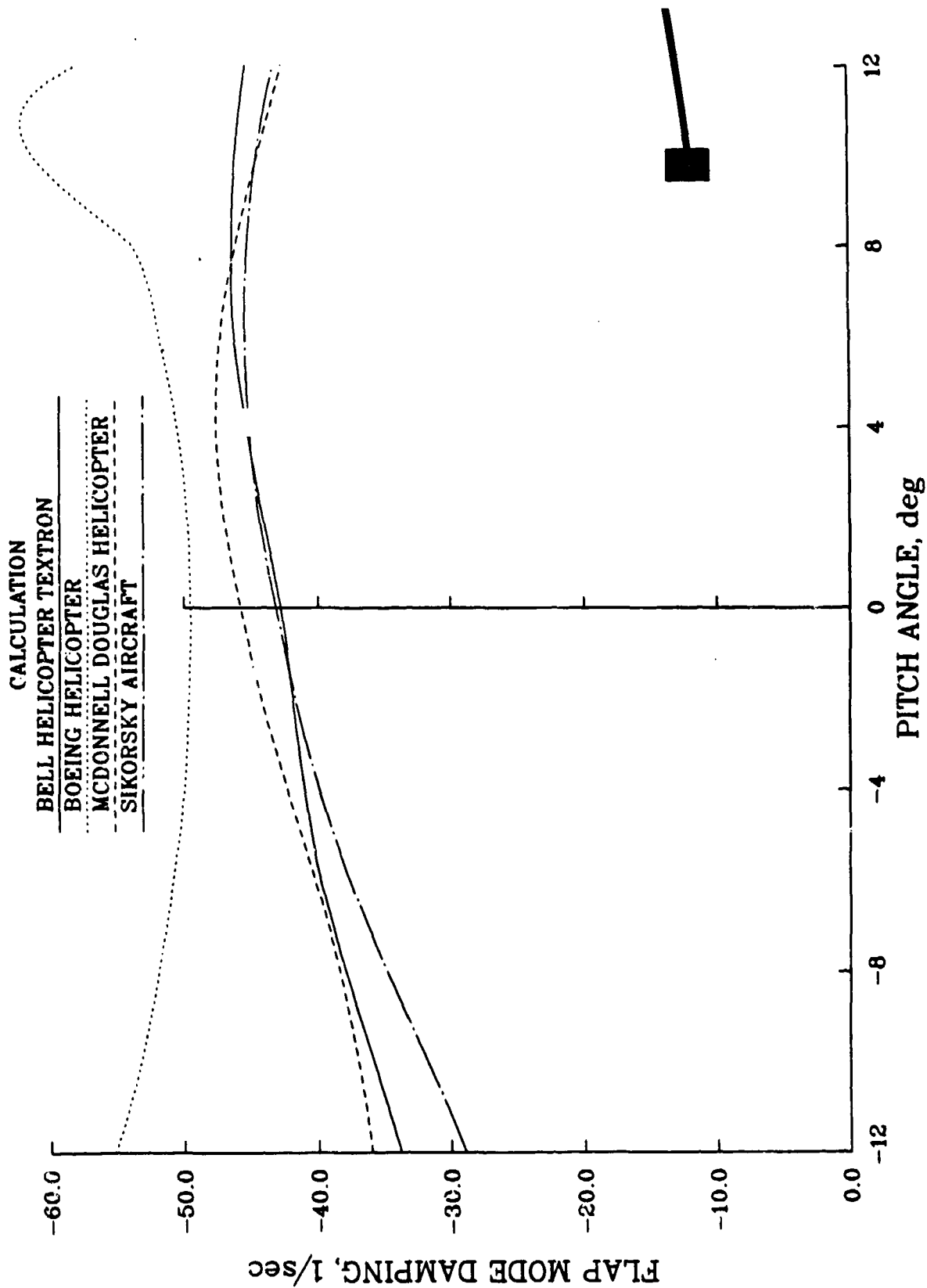


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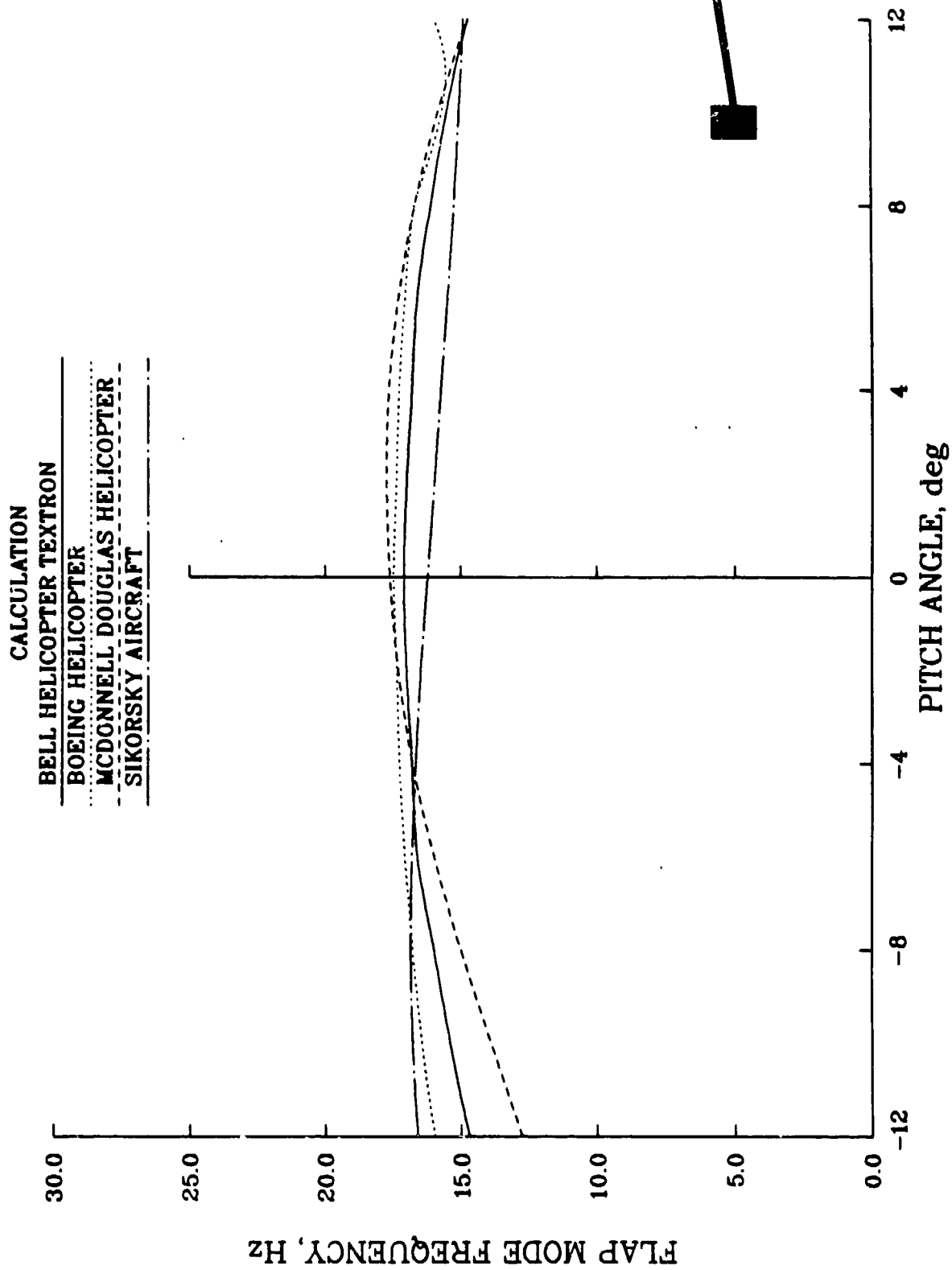




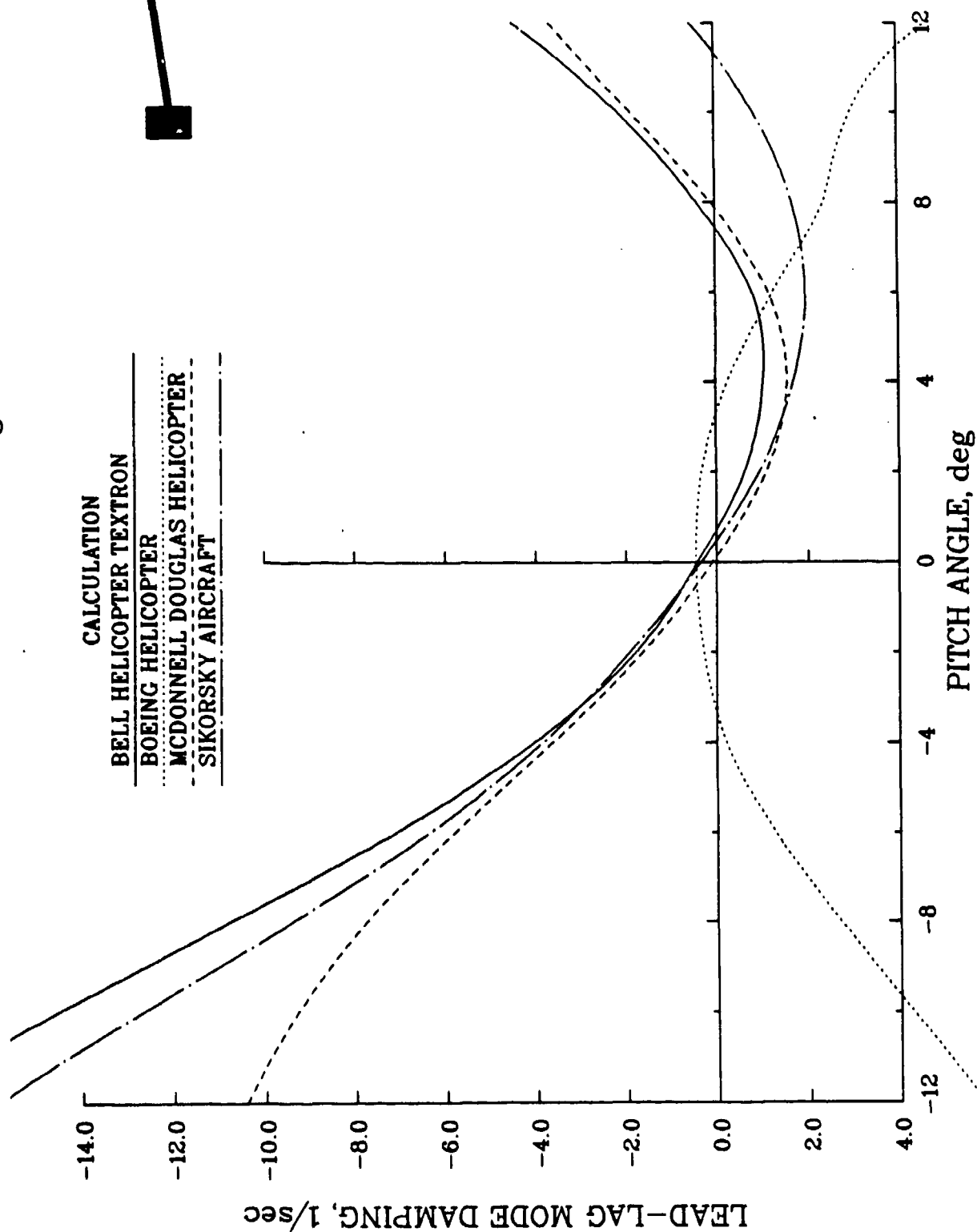
# FLAP MODE DAMPING - TASK 86i SIMPLIFIED ROTOR WITH 5 deg. PRECONE



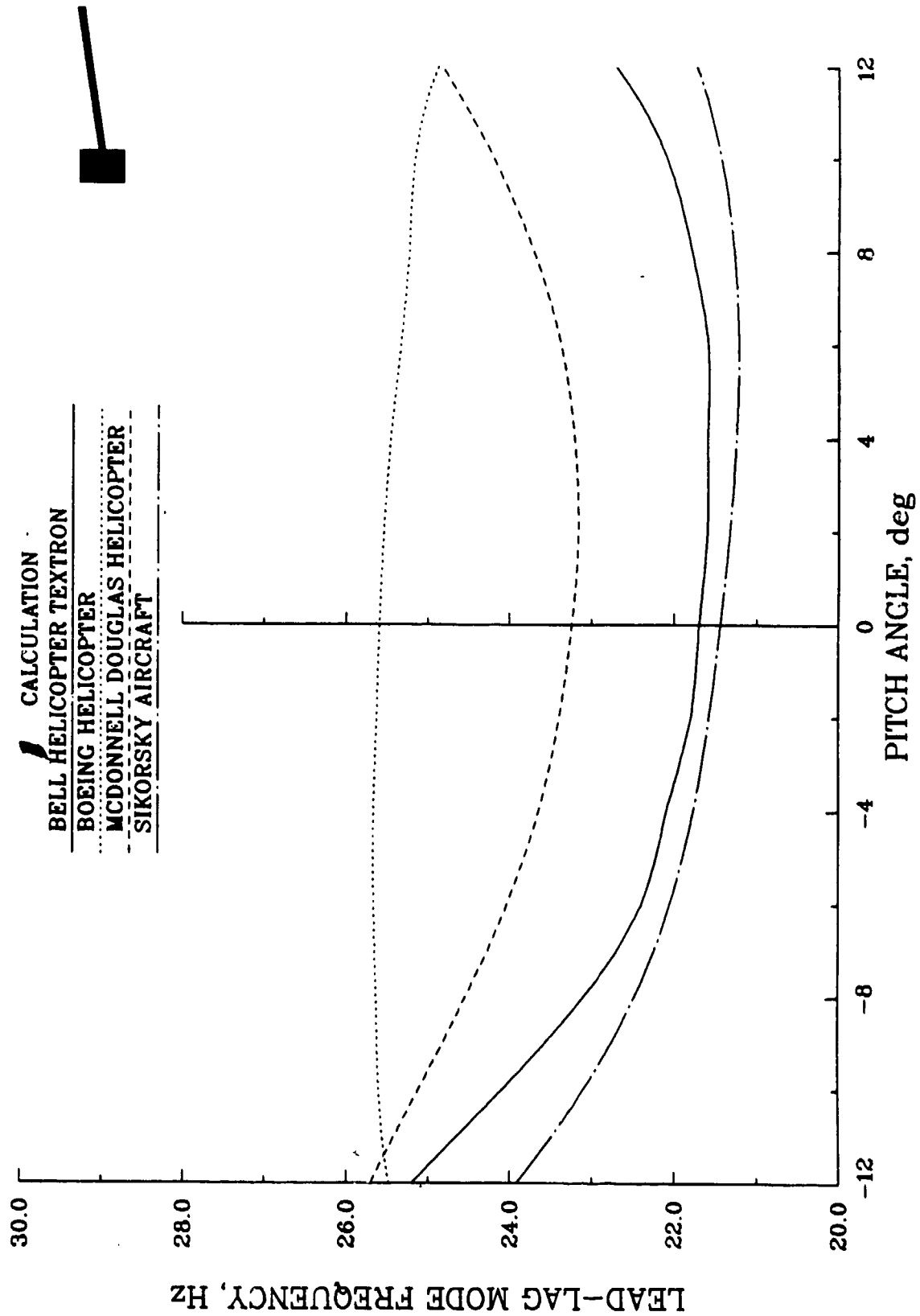
# FLAP MODE FREQUENCY - TASK 86i SIMPLIFIED ROTOR WITH 5 deg. PRECONE



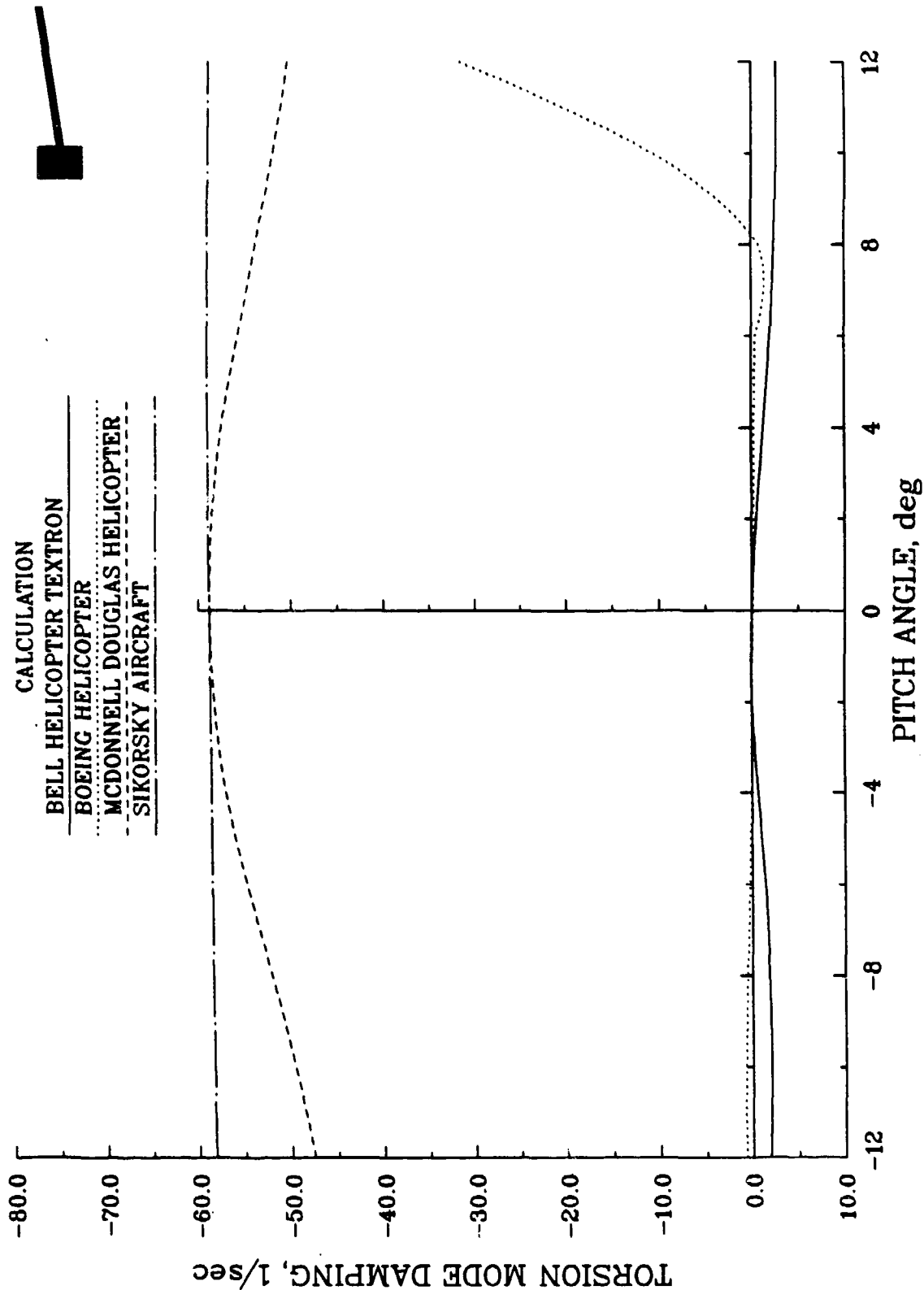
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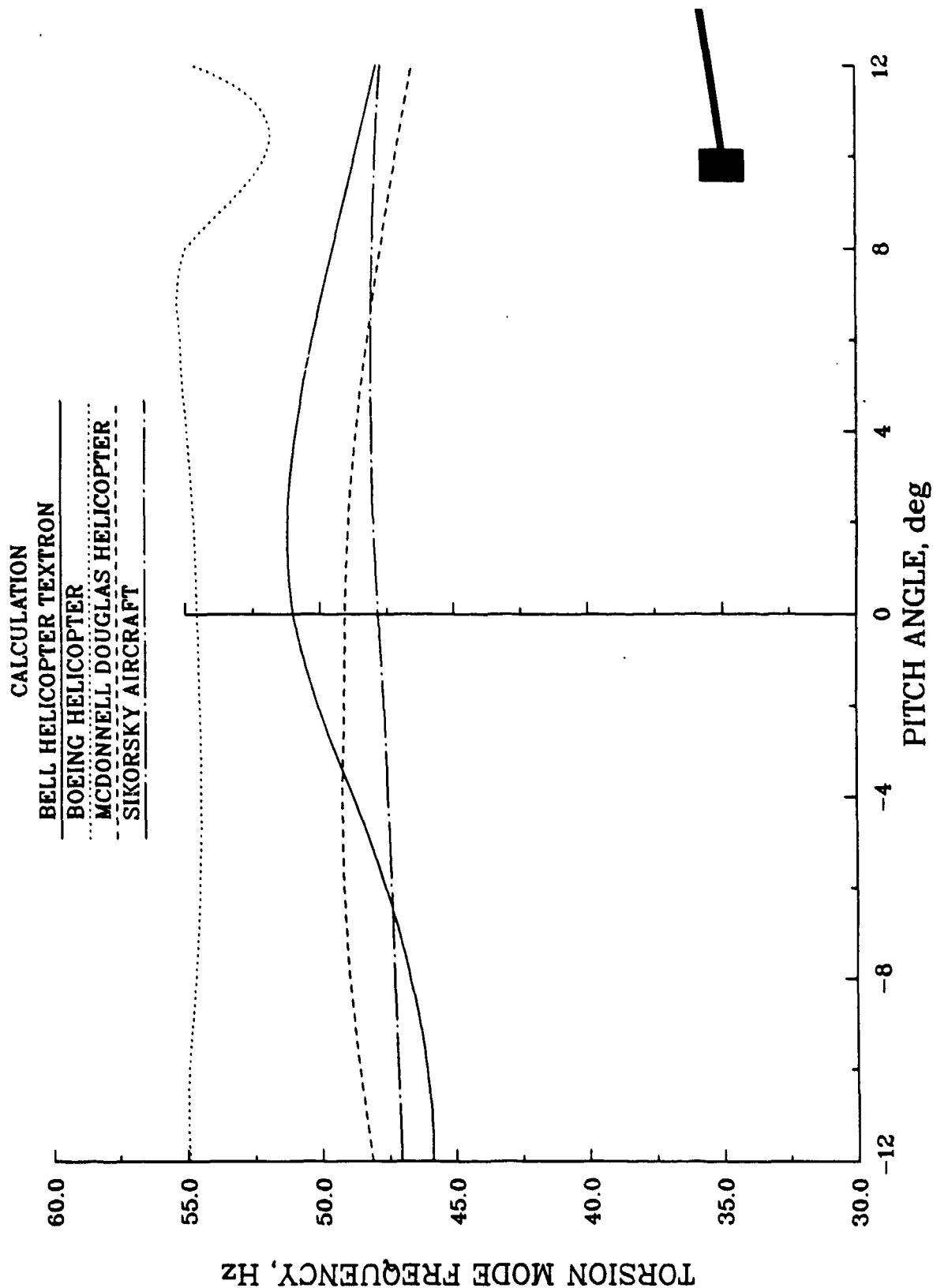
# LEAD-LAG MODE FREQUENCY - TASK 86i SIMPLIFIED ROTOR WITH 5 deg. PRECONE



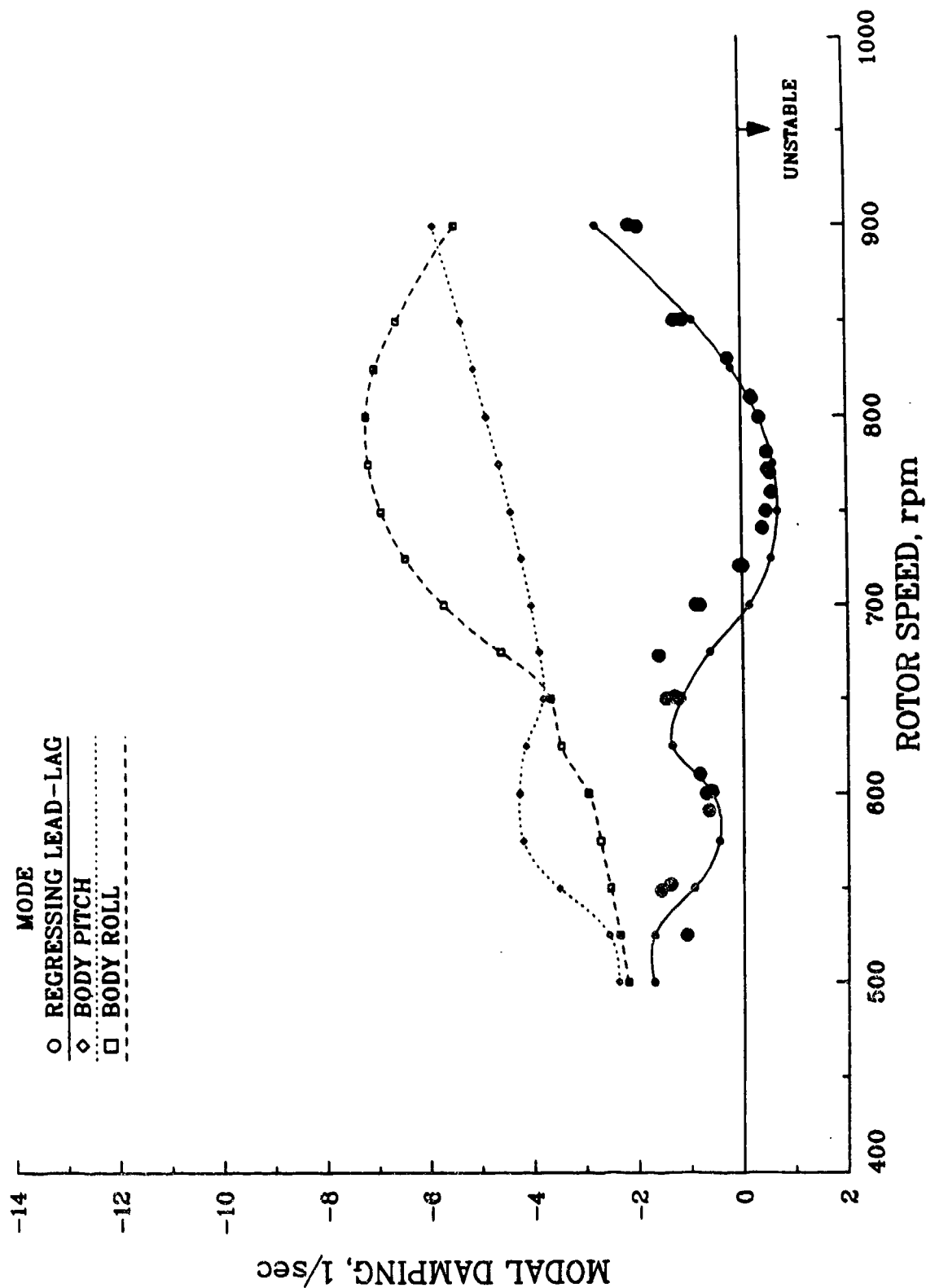
# TORSION MODE DAMPING - TASK 86i SIMPLIFIED ROTOR WITH 5 deg. PRECONE



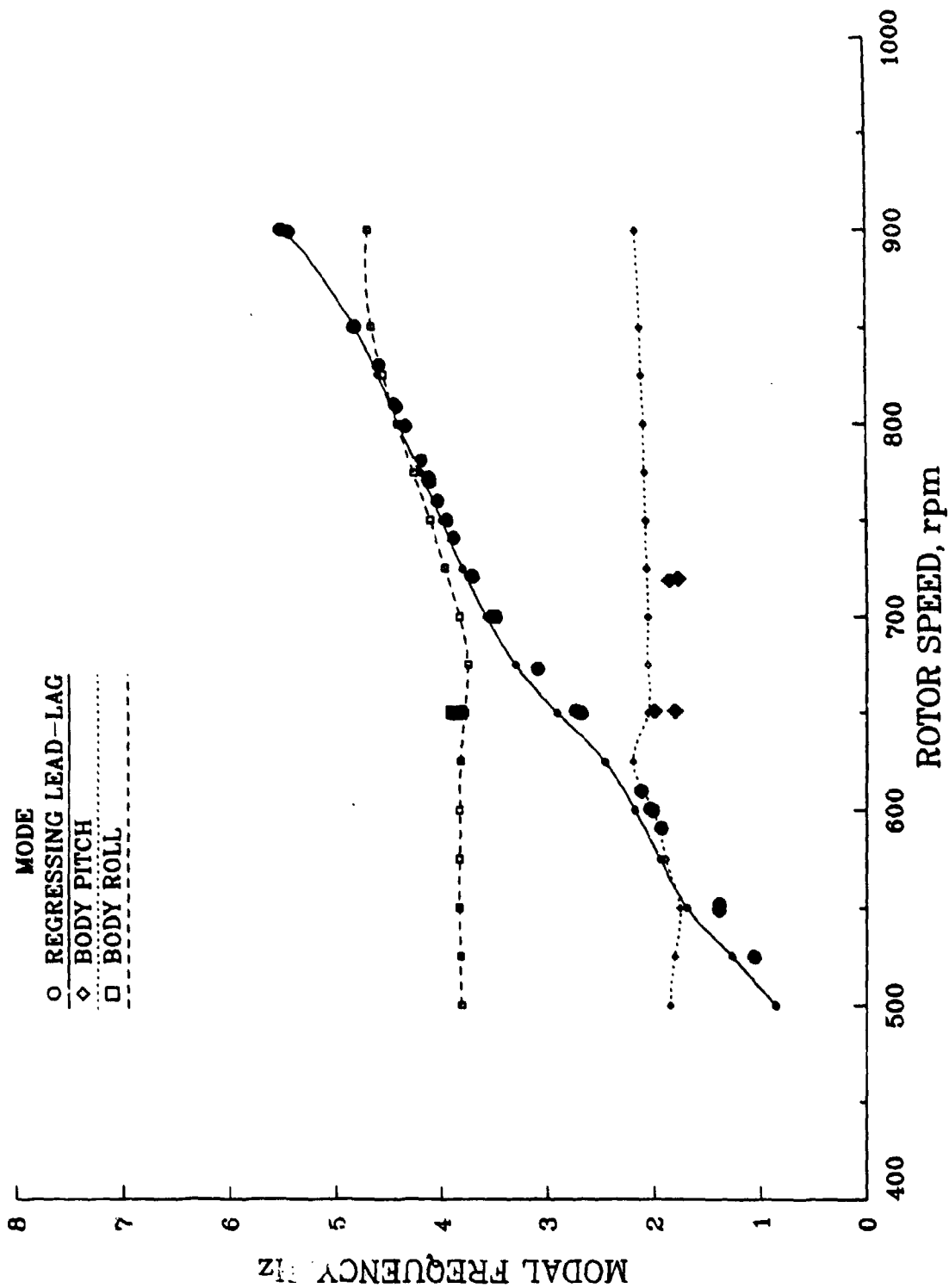
# TORSION MODE FREQUENCY - TASK 86i SIMPLIFIED ROTOR WITH 5 deg. PRECONE



MODAL DAMPING - TASK 84-2  
 CONFIGURATION 3, PITCH ANGLE = 9 deg  
 BELL HELICOPTER TEXTRON

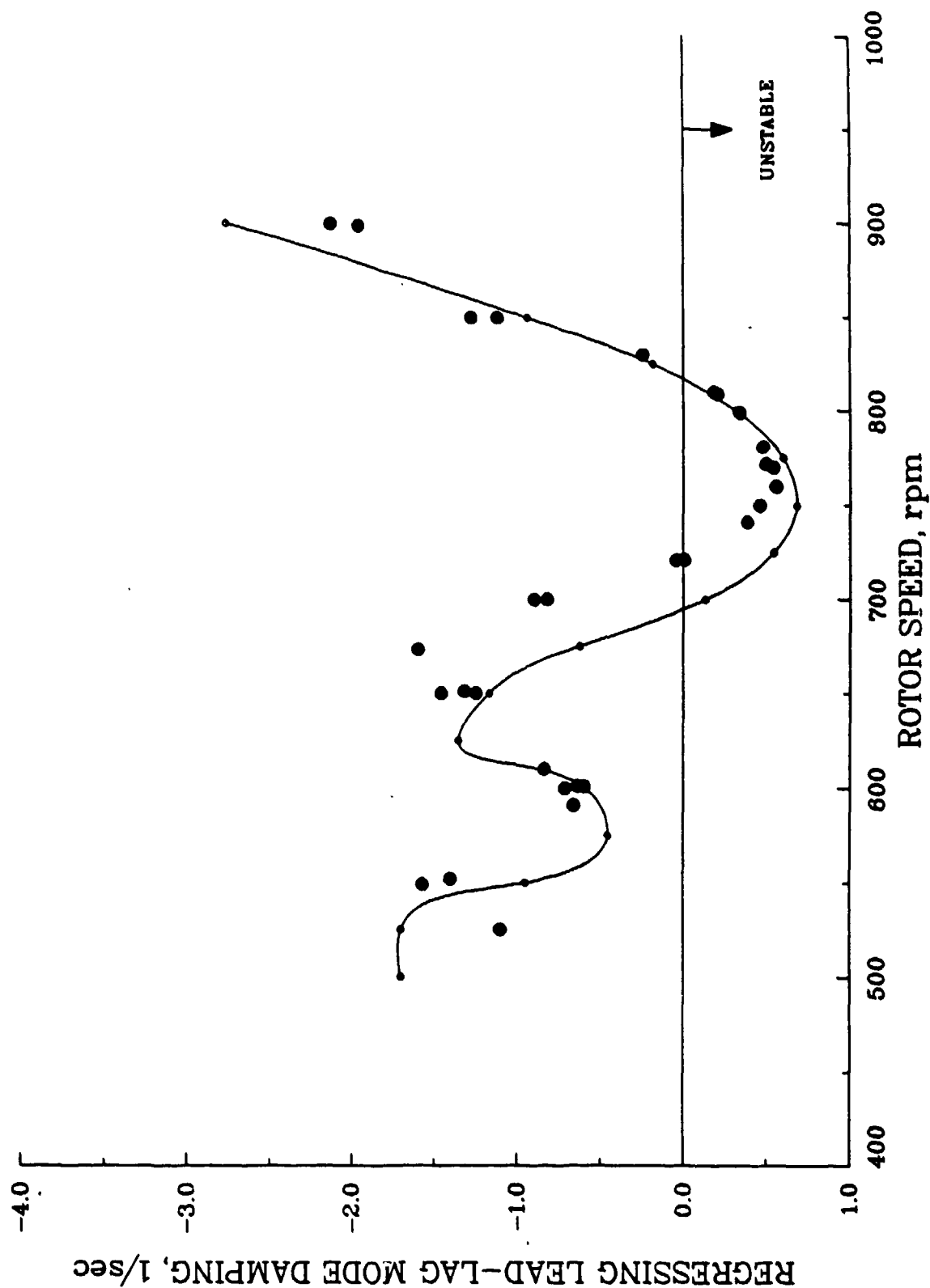


MODAL FREQUENCY - TASK 84-2  
 CONFIGURATION 3, PITCH ANGLE = 9 deg  
 BELL HELICOPTER TEXTRON

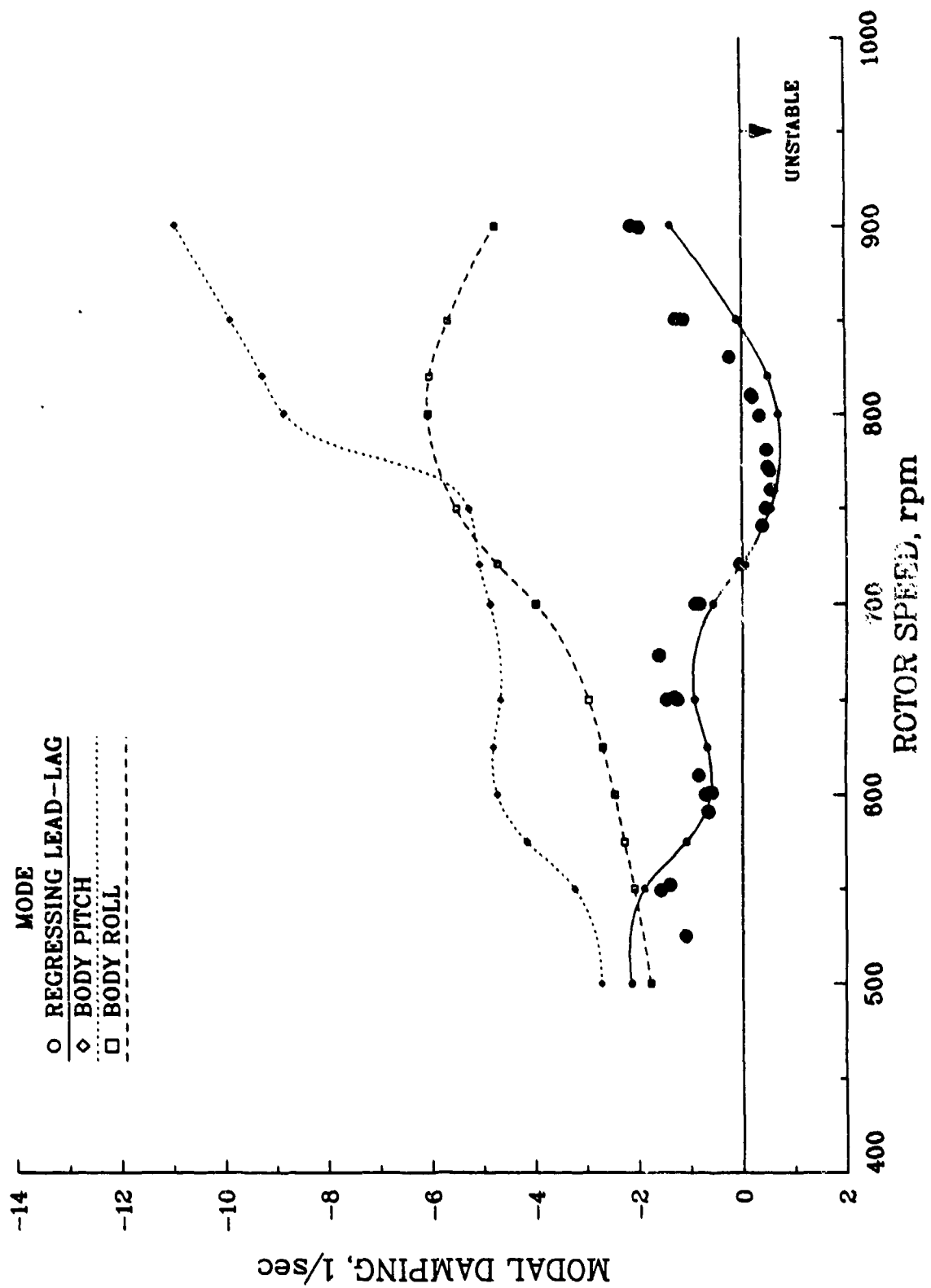




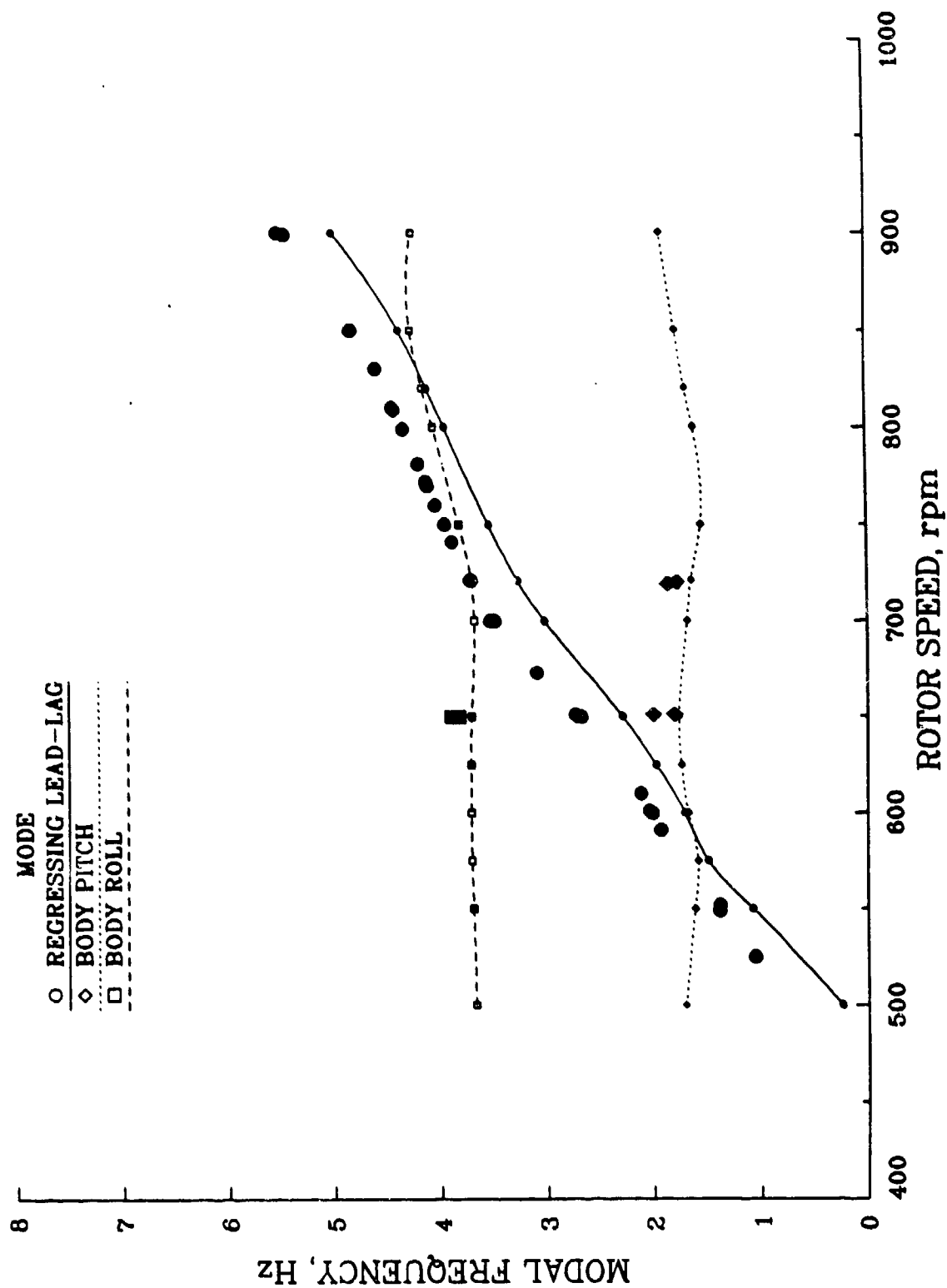
REGRESSING LEAD-LAG MODE DAMPING - TASK 84-2  
 CONFIGURATION 3, PITCH ANGLE = 9 deg  
 BELL HELICOPTER TEXTRON



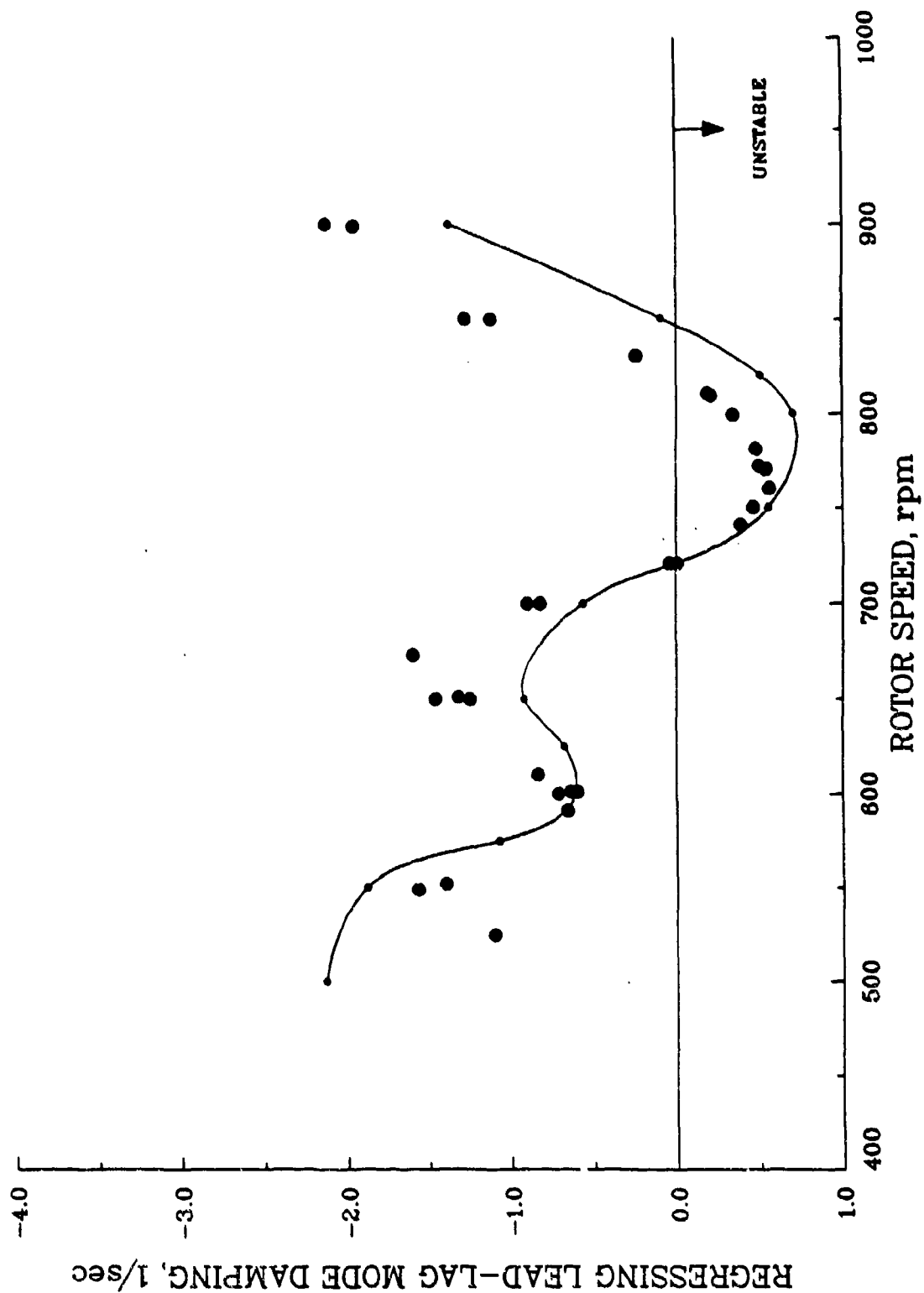
MODAL DAMPING - TASK 84-2  
 CONFIGURATION 3, PITCH ANGLE = 9 deg  
 BOEING HELICOPTER



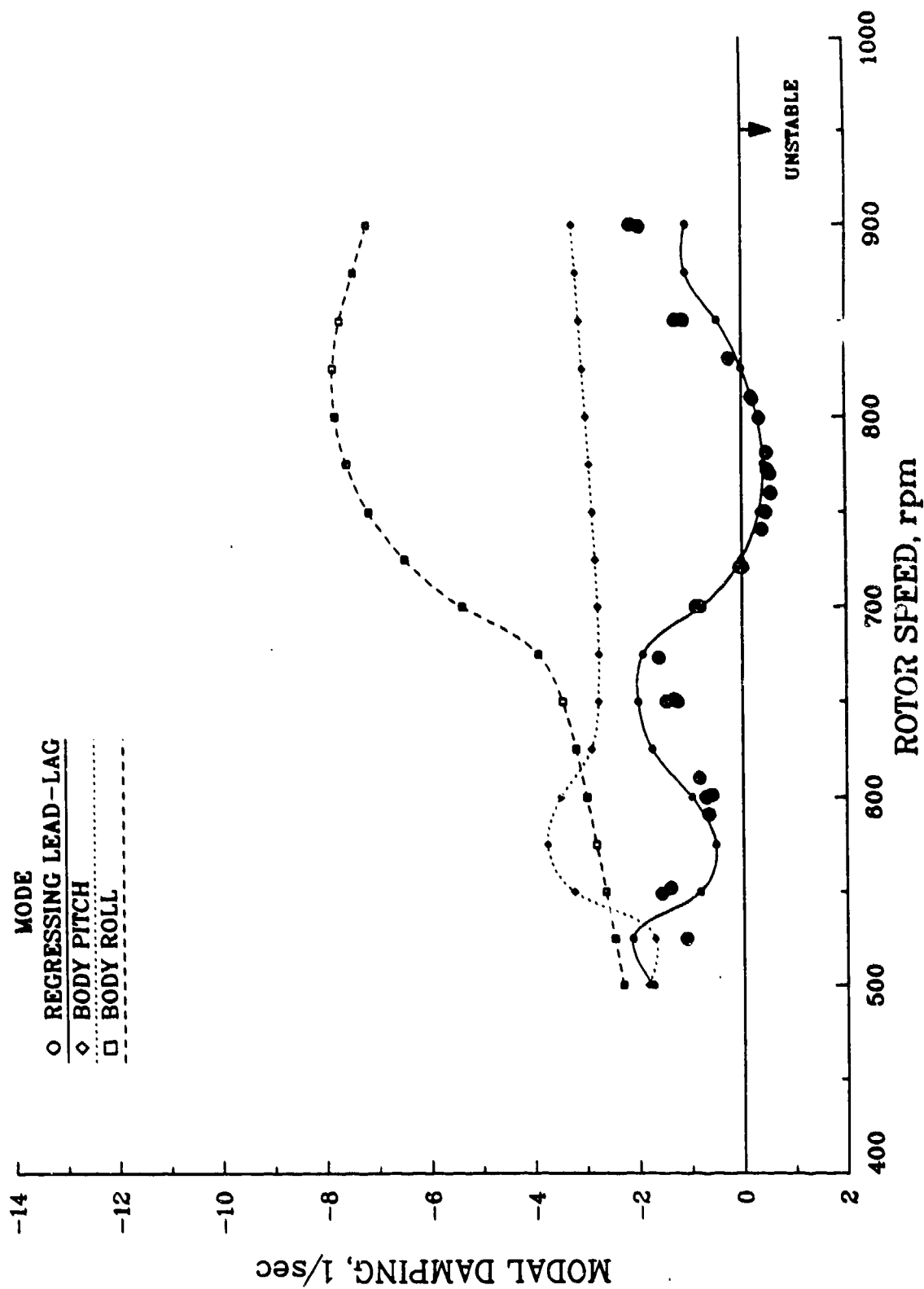
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 CONFIGURATION 3, PITCH ANGLE = 9 deg  
 BOEING HELICOPTER



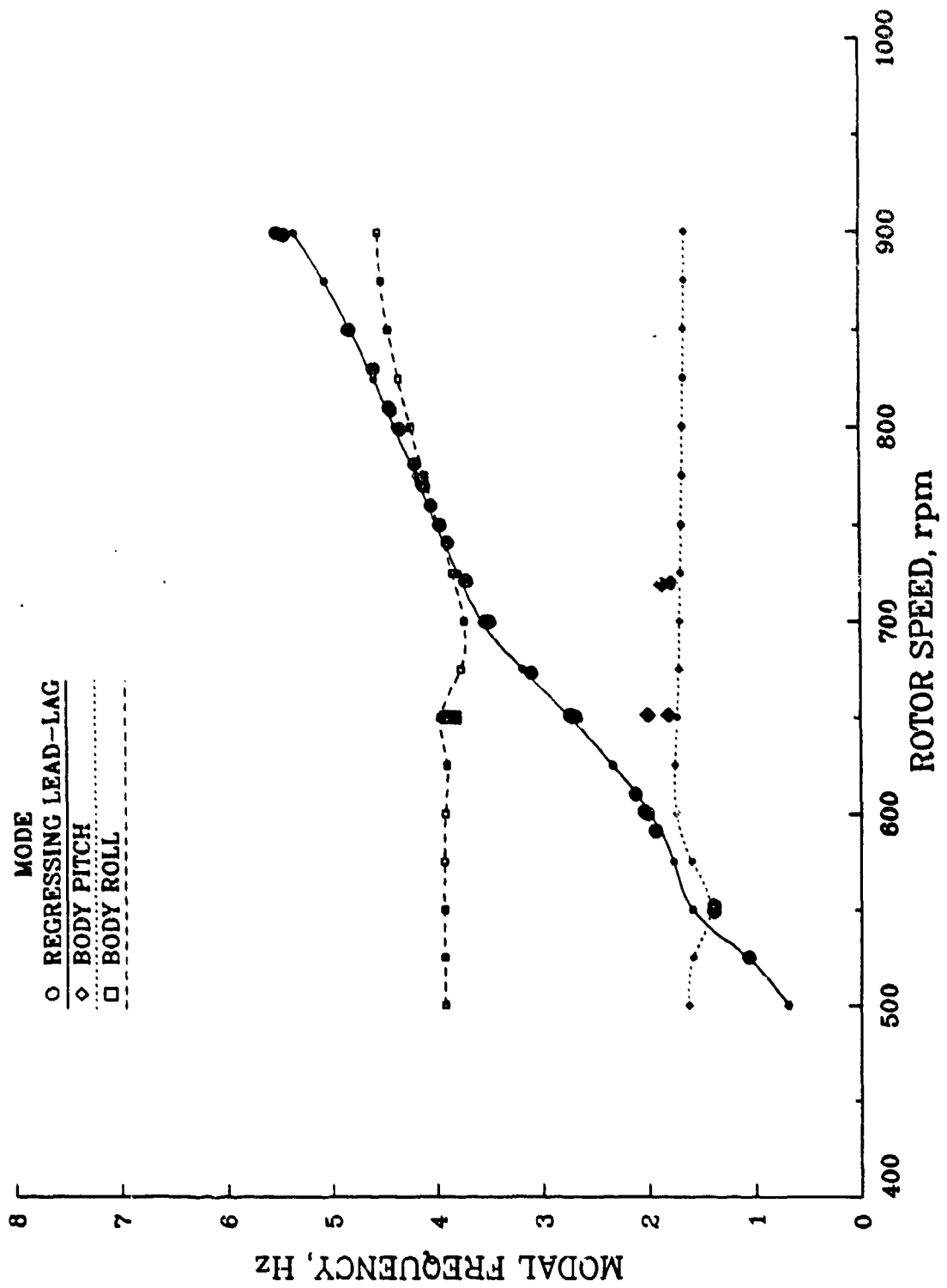
REGRESSING LEAD-LAG MODE DAMPING - TASK 84-2  
 CONFIGURATION 3, PITCH ANGLE = 9 deg  
 BOEING HELICOPTER



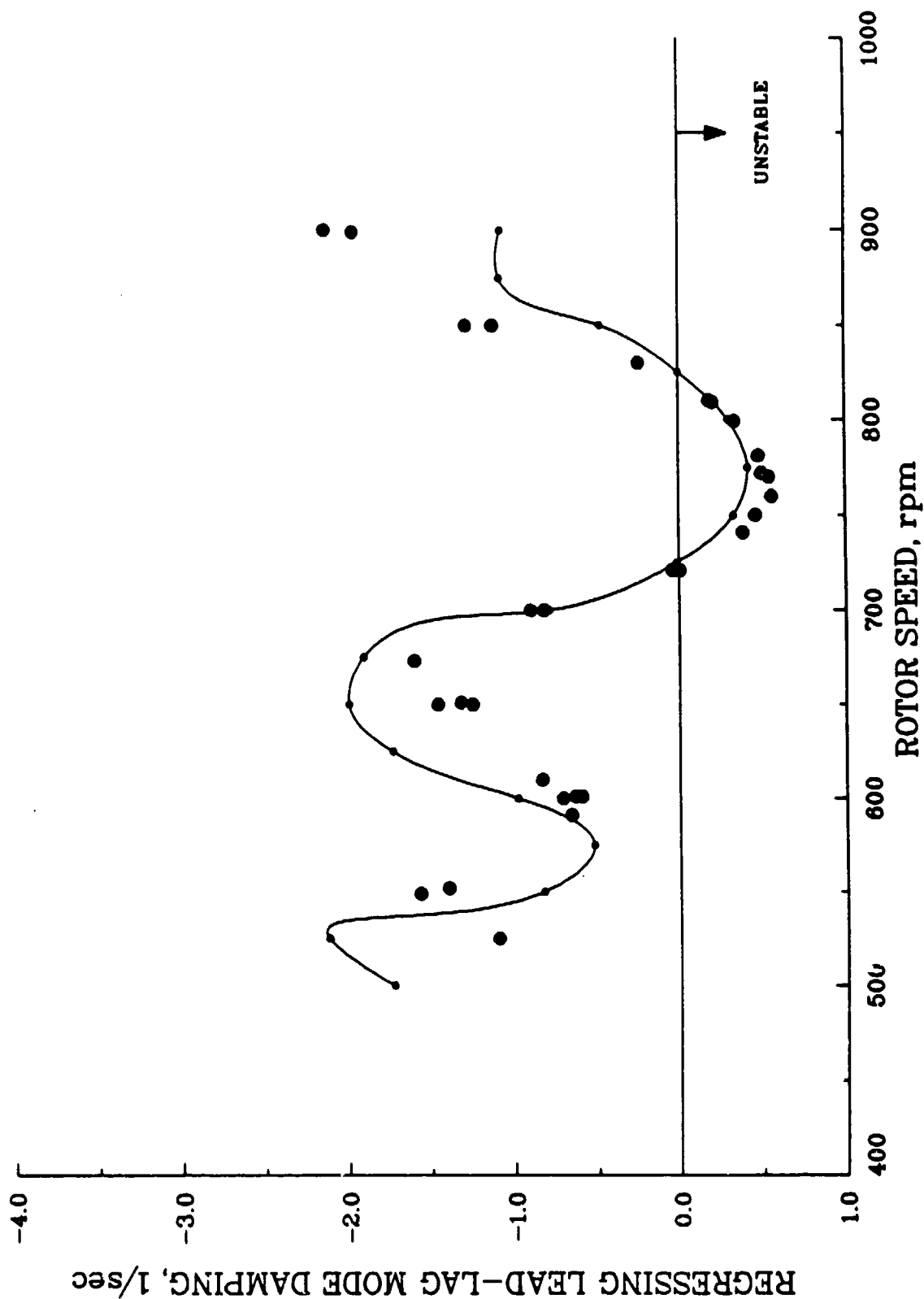
# MODAL DAMPING - TASK 84-2 CONFIGURATION 3, PITCH ANGLE = 9 deg SIKORSKY AIRCRAFT



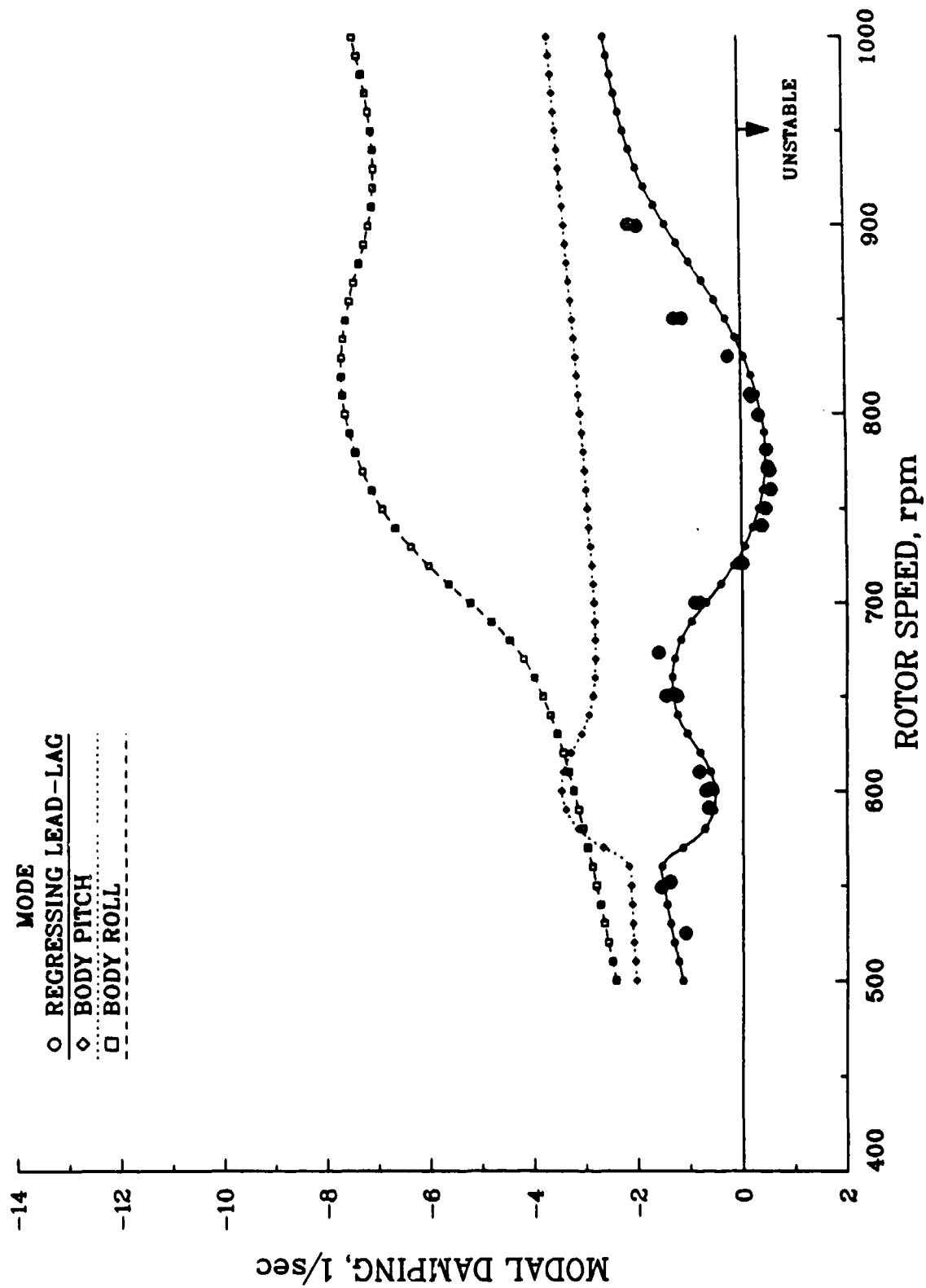
MODAL FREQUENCY - TASK 84-2  
 CONFIGURATION 3, PITCH ANGLE = 9 deg  
 SIKORSKY AIRCRAFT



REGRESSING LEAD-LAG MODE DAMPING - TASK 84-2  
 CONFIGURATION 3, PITCH ANGLE = 9 deg  
 SIKORSKY AIRCRAFT

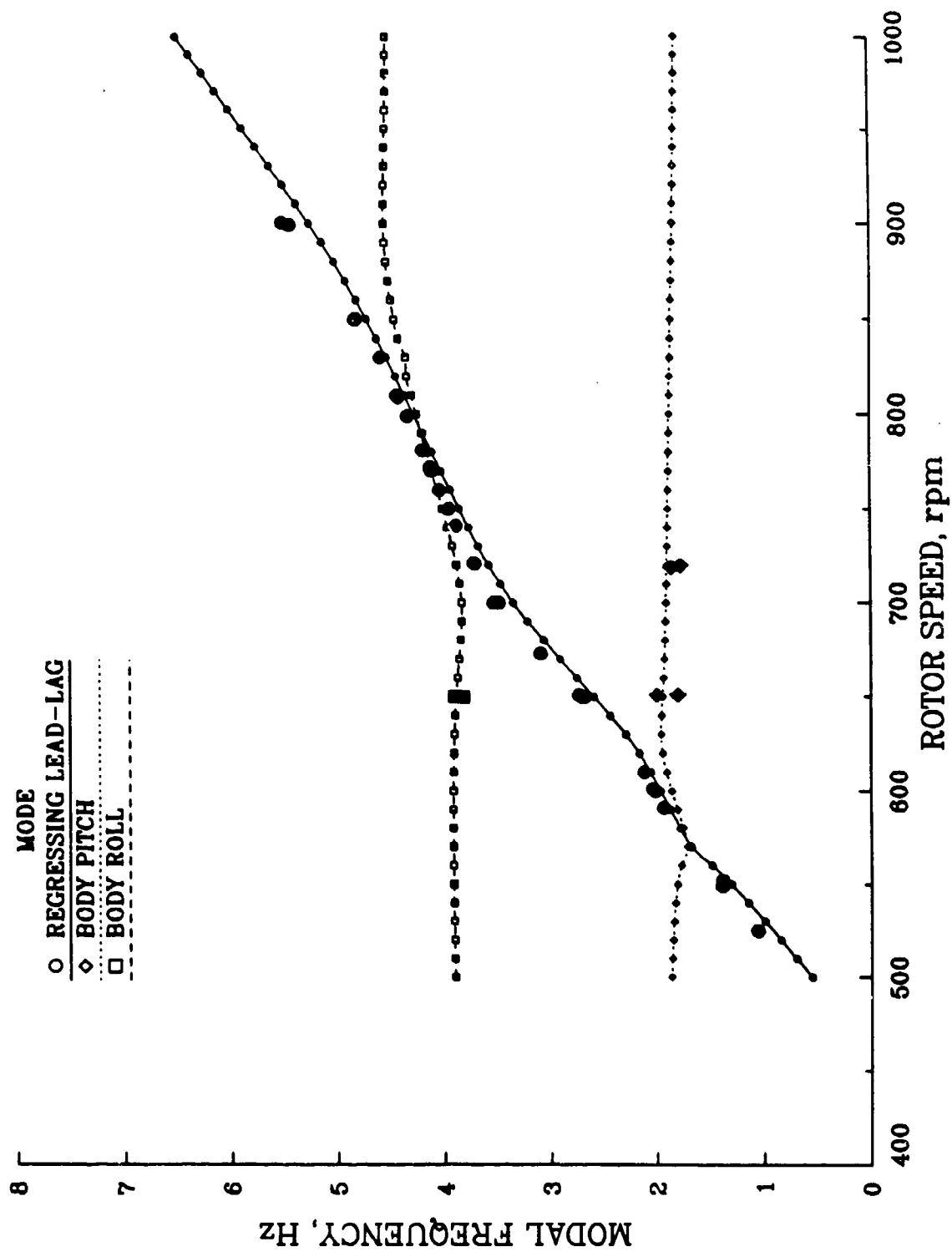


MODAL DAMPING - TASK 84-2  
 CONFIGURATION 3, PITCH ANGLE = 9 deg  
 AEROFLIGHTDYNAMICS

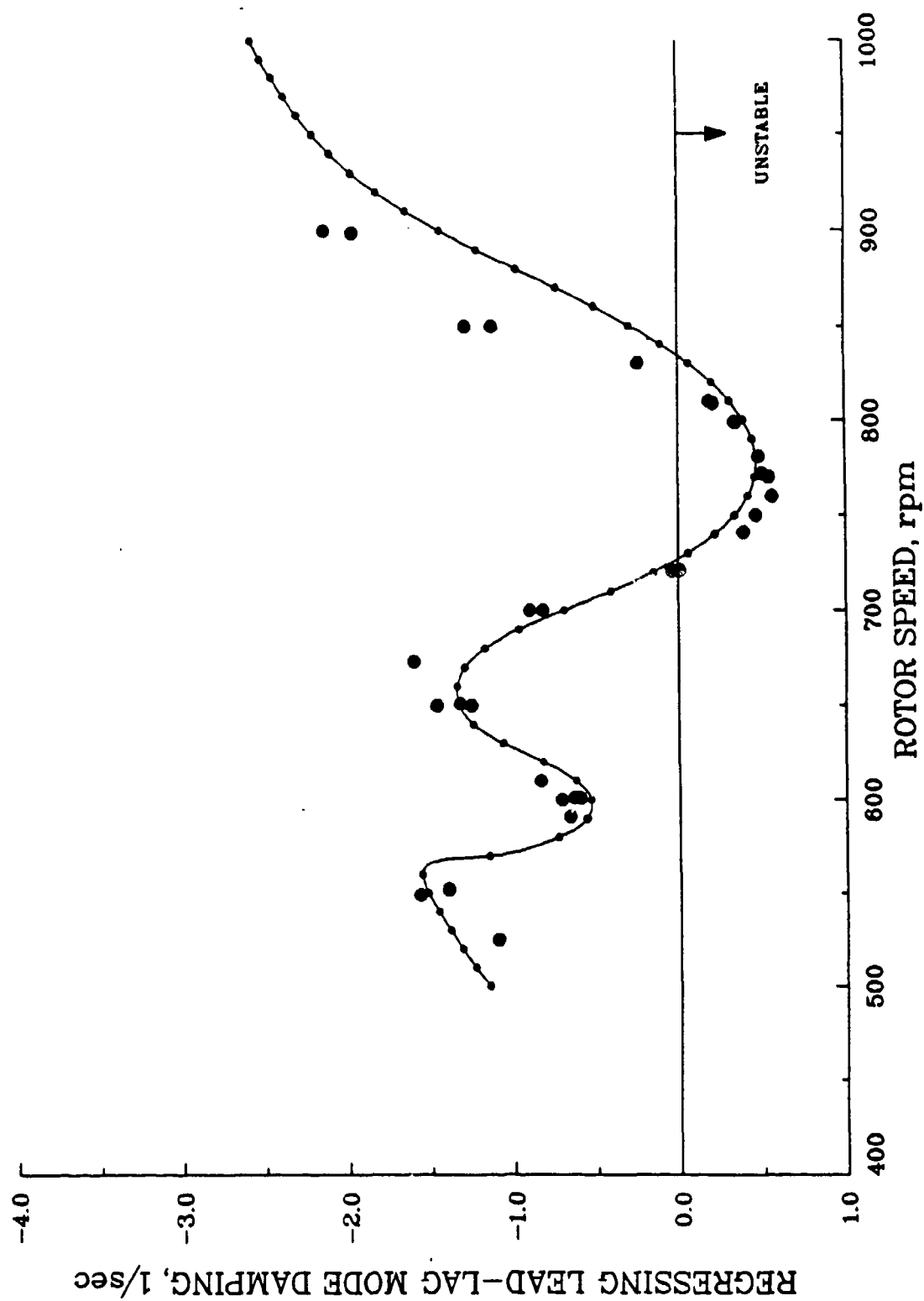




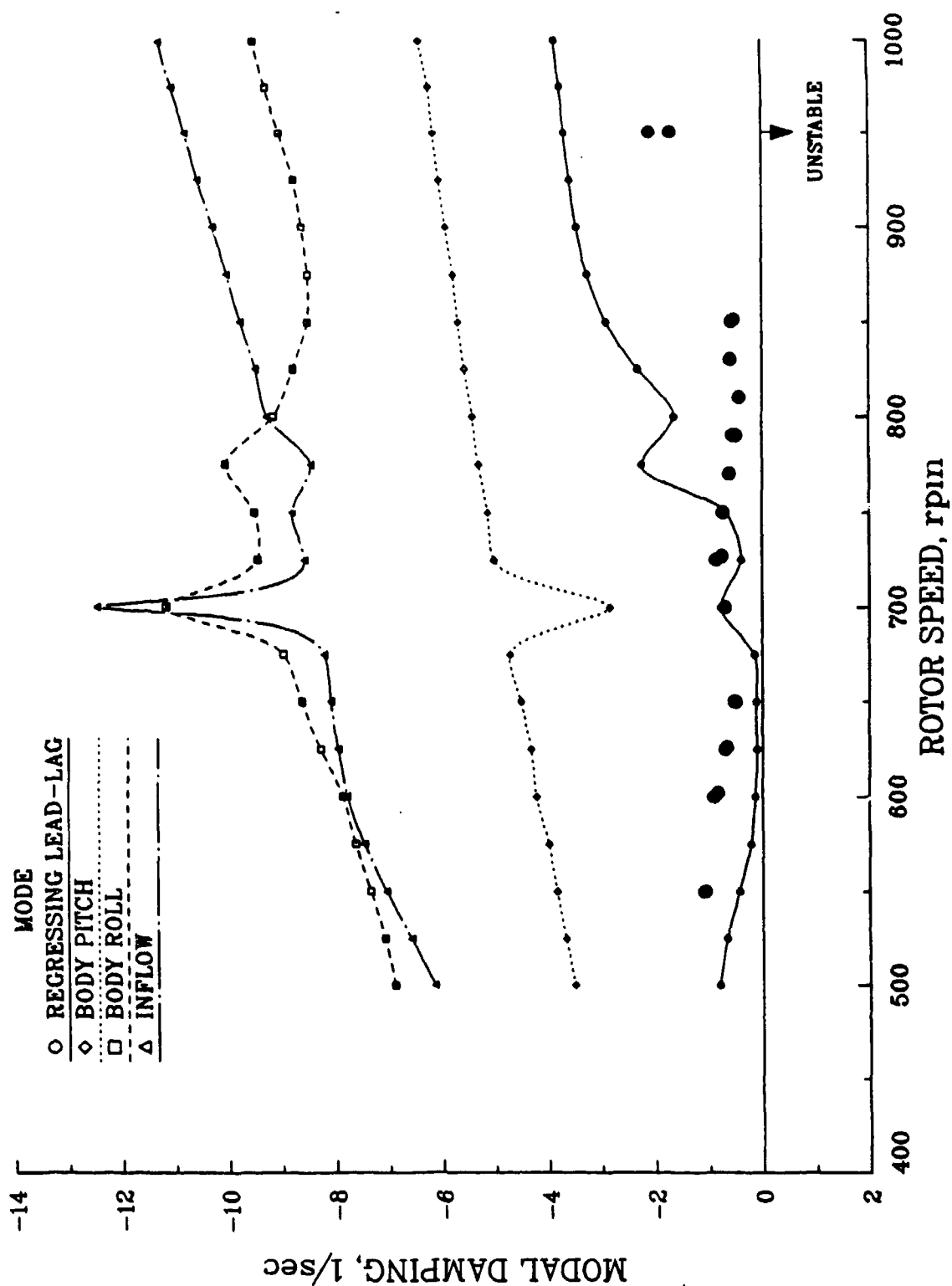
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 AEROFLIGHTDYNAMICS



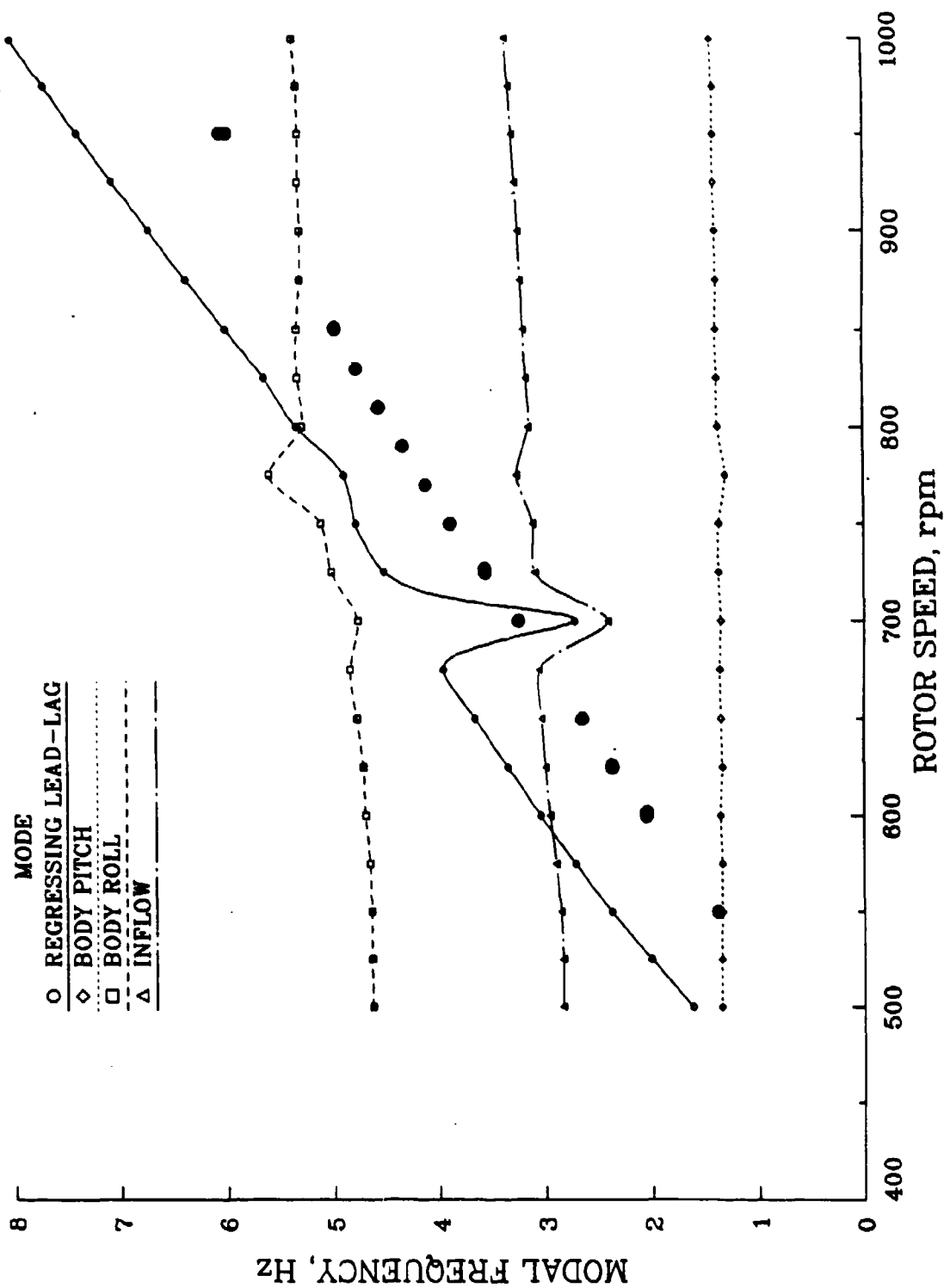
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 CONFIGURATION 3, PITCH ANGLE = 9 deg  
 AEROFLIGHTDYNAMICS



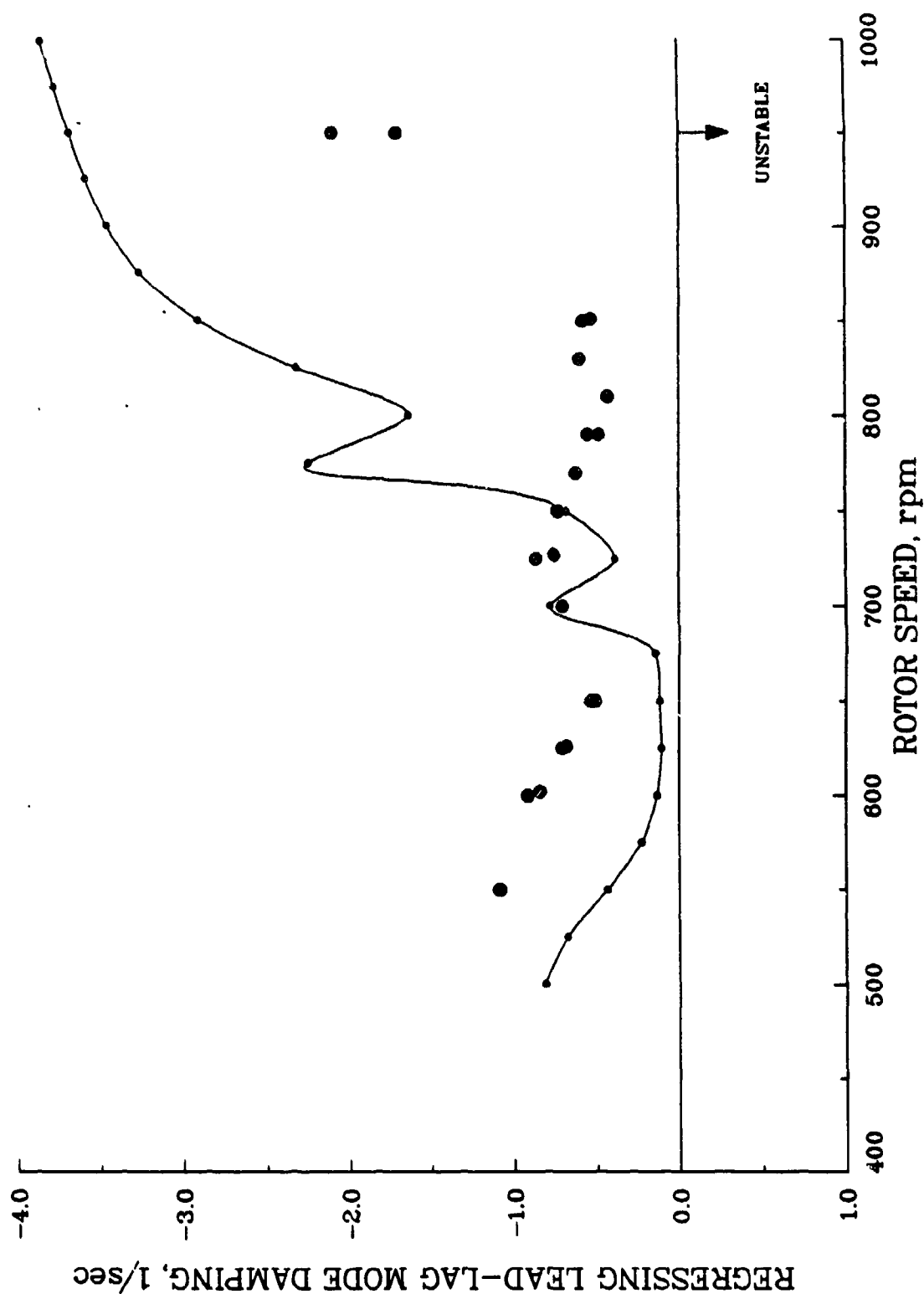
MODAL DAMPING - TASK 86j  
 CONFIGURATION 5, PITCH ANGLE = 9 deg  
 BELL HELICOPTER TEXTRON



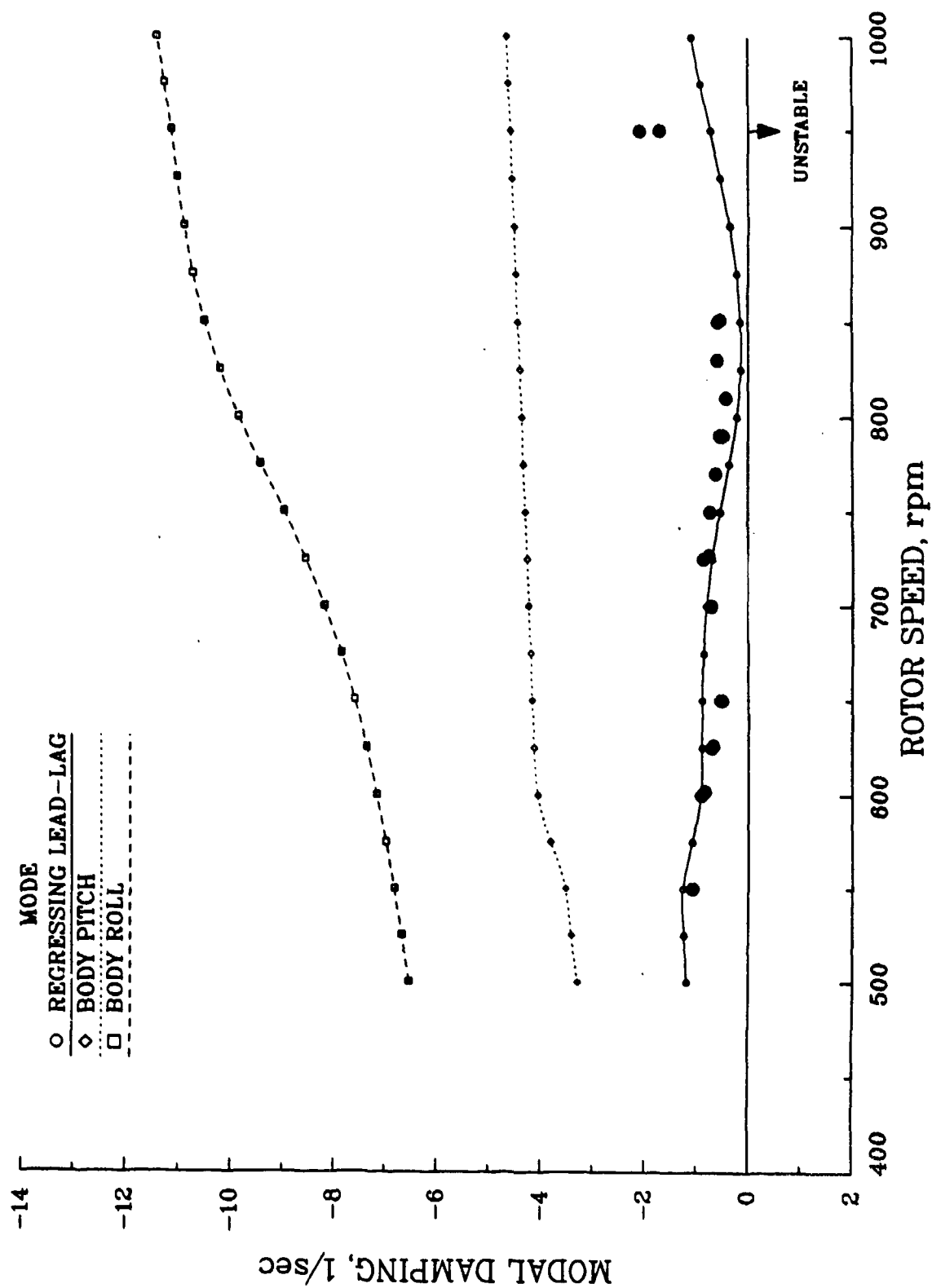
MODAL FREQUENCY - TASK 86j  
 CONFIGURATION 5, PITCH ANGLE = 9 deg  
 BELL HELICOPTER TEXTRON



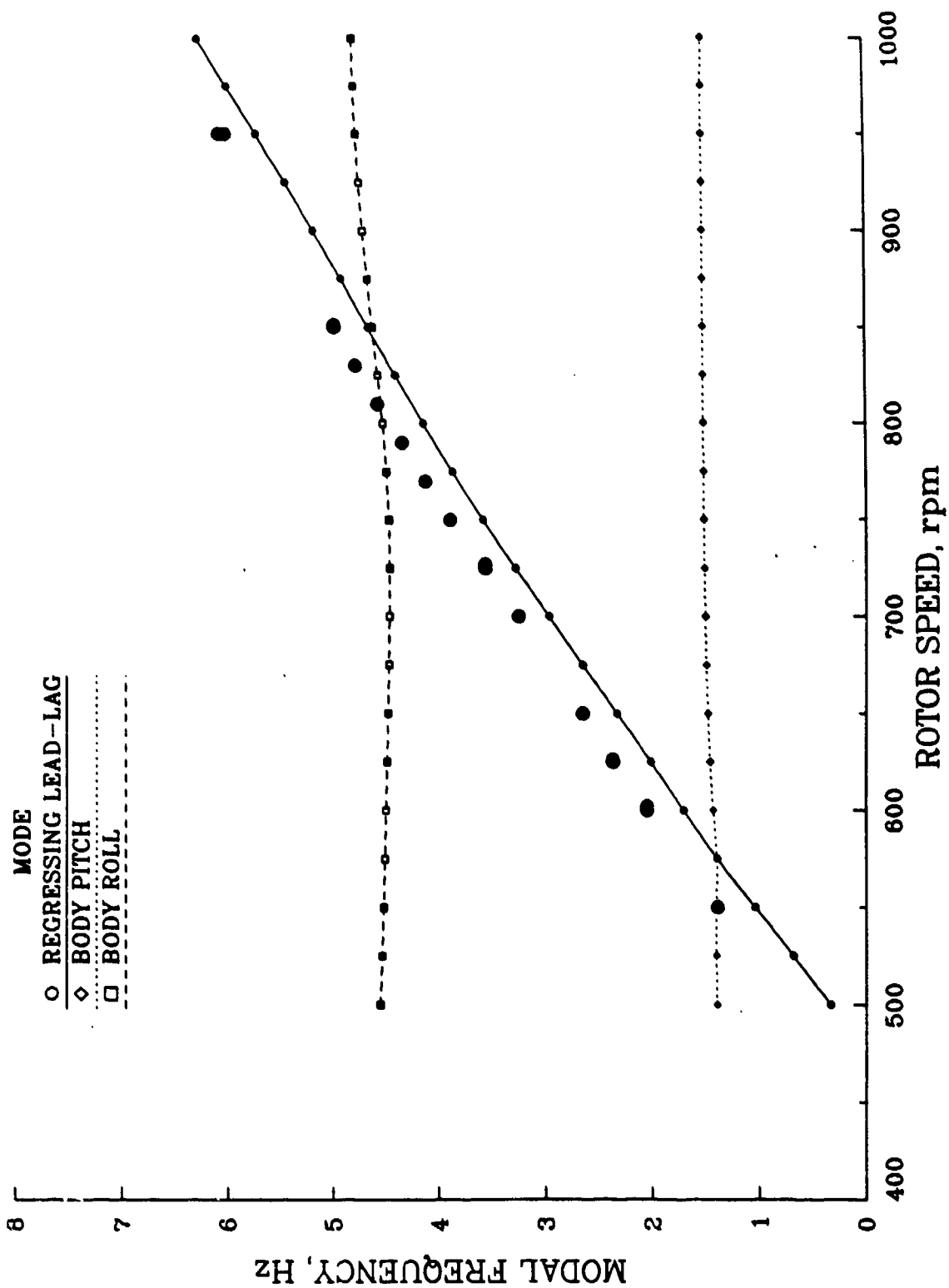
REGRESSING LEAD-LAG MODE DAMPING - TASK 86j  
 CONFIGURATION 5, PITCH ANGLE = 9 deg  
 BELL HELICOPTER TEXTRON



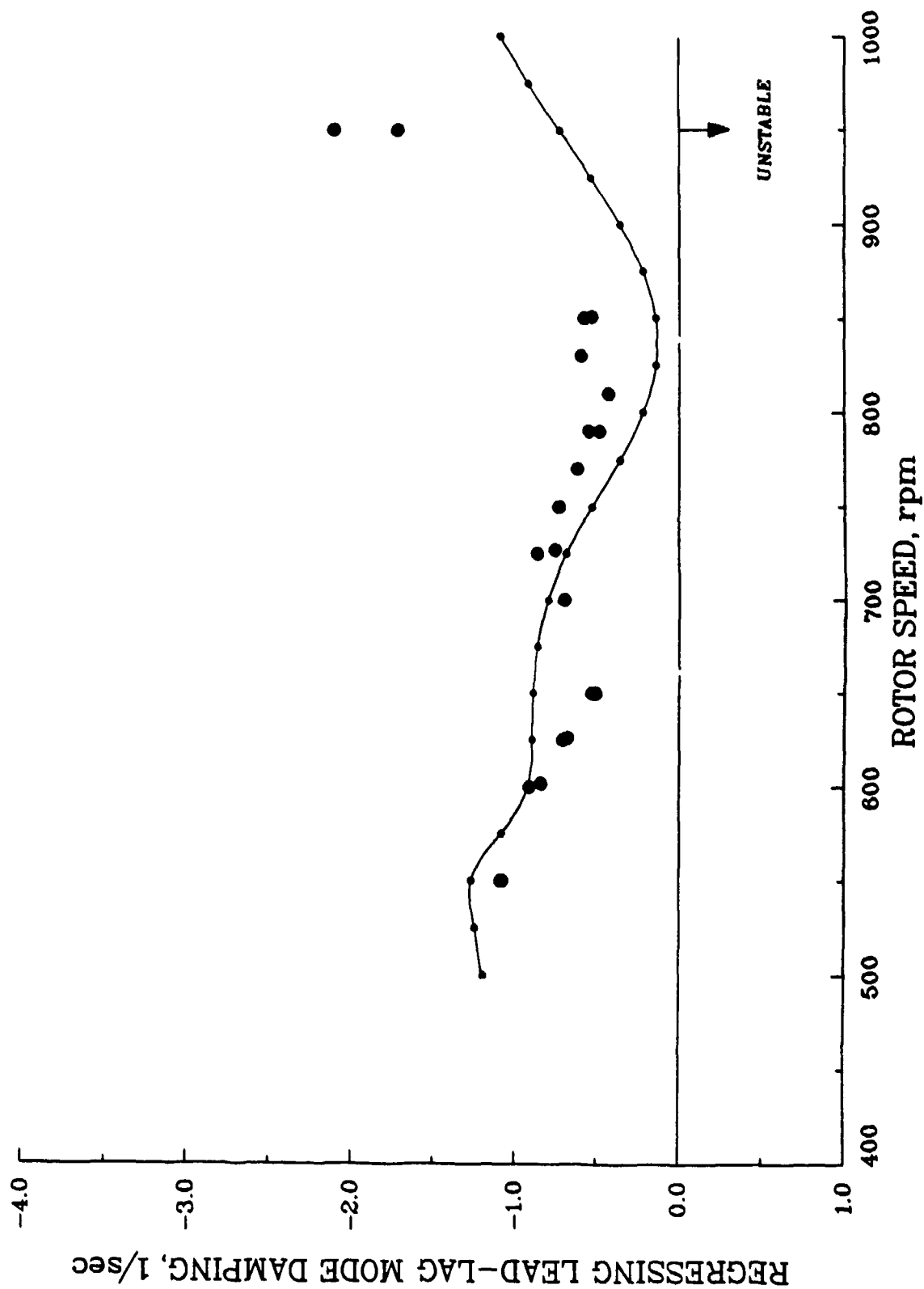
MODAL DAMPING - TASK 86j  
 CONFIGURATION 5, PITCH ANGLE = 9 deg  
 SIKORSKY AIRCRAFT



MODAL FREQUENCY - TASK 86j  
 CONFIGURATION 5, PITCH ANGLE = 9 deg  
 SIKORSKY AIRCRAFT

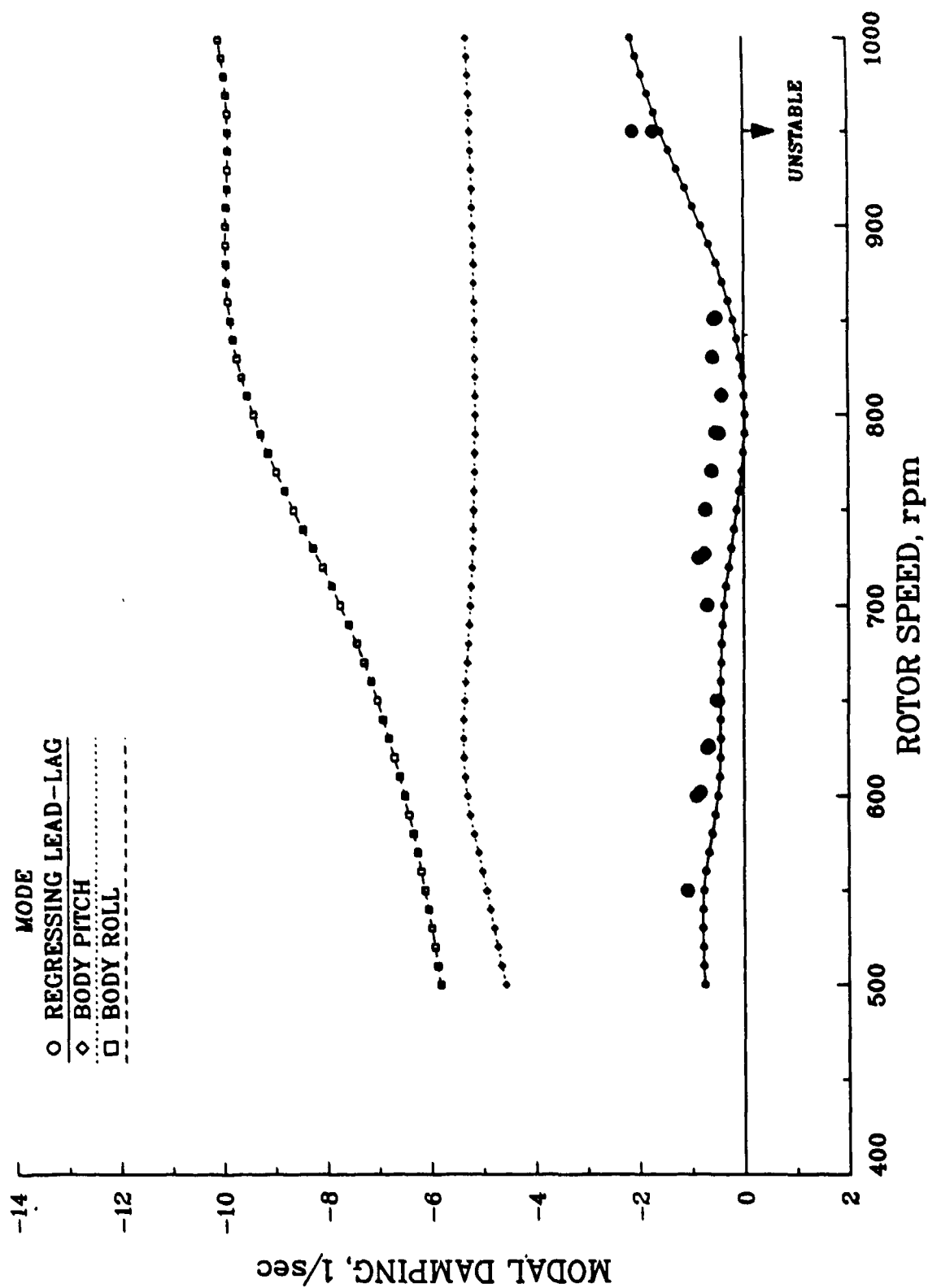


REGRESSING LEAD-LAG MODE DAMPING - TASK 86j  
 CONFIGURATION 5, PITCH ANGLE = 9 deg  
 SIKORSKY AIRCRAFT

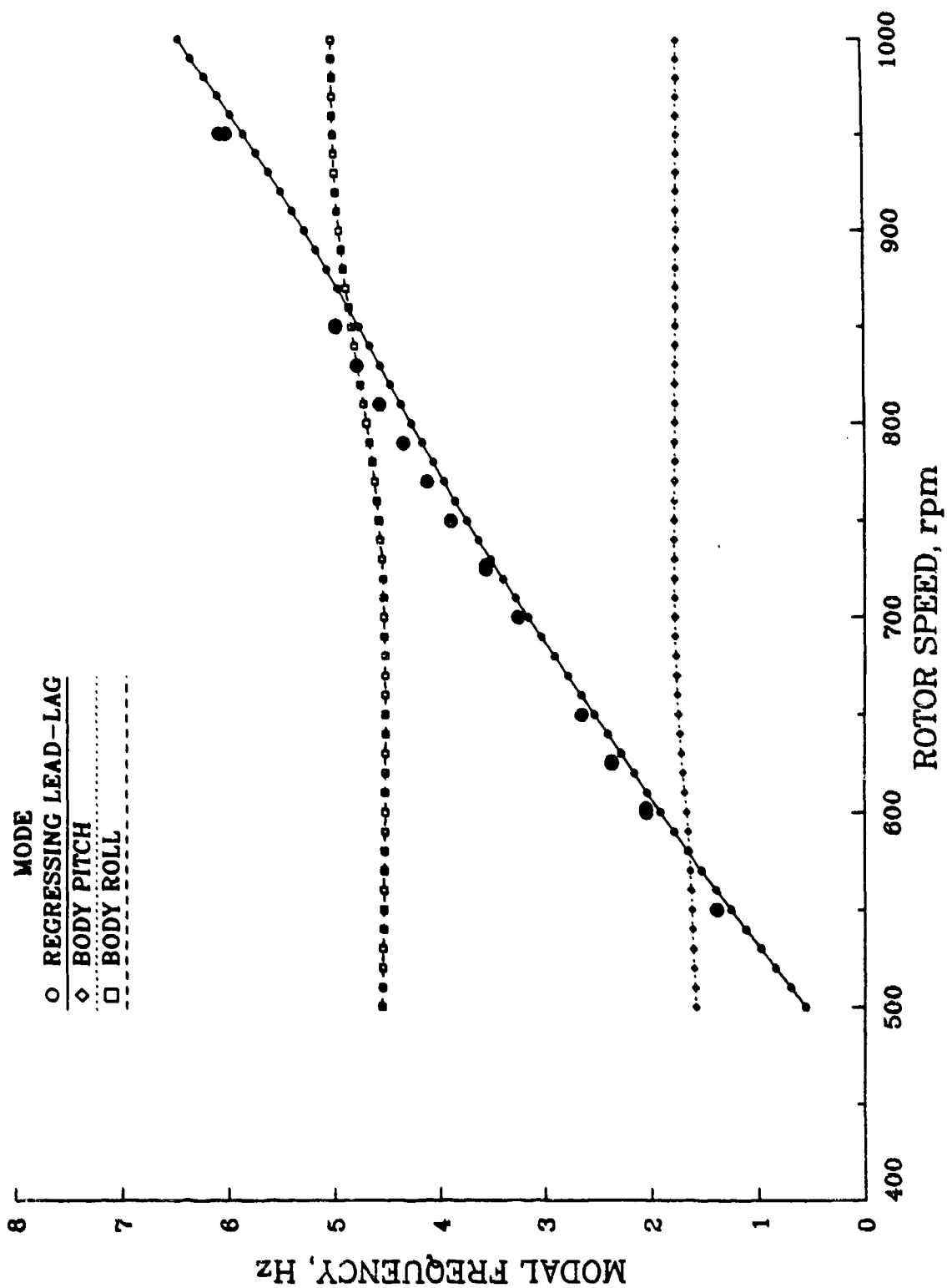




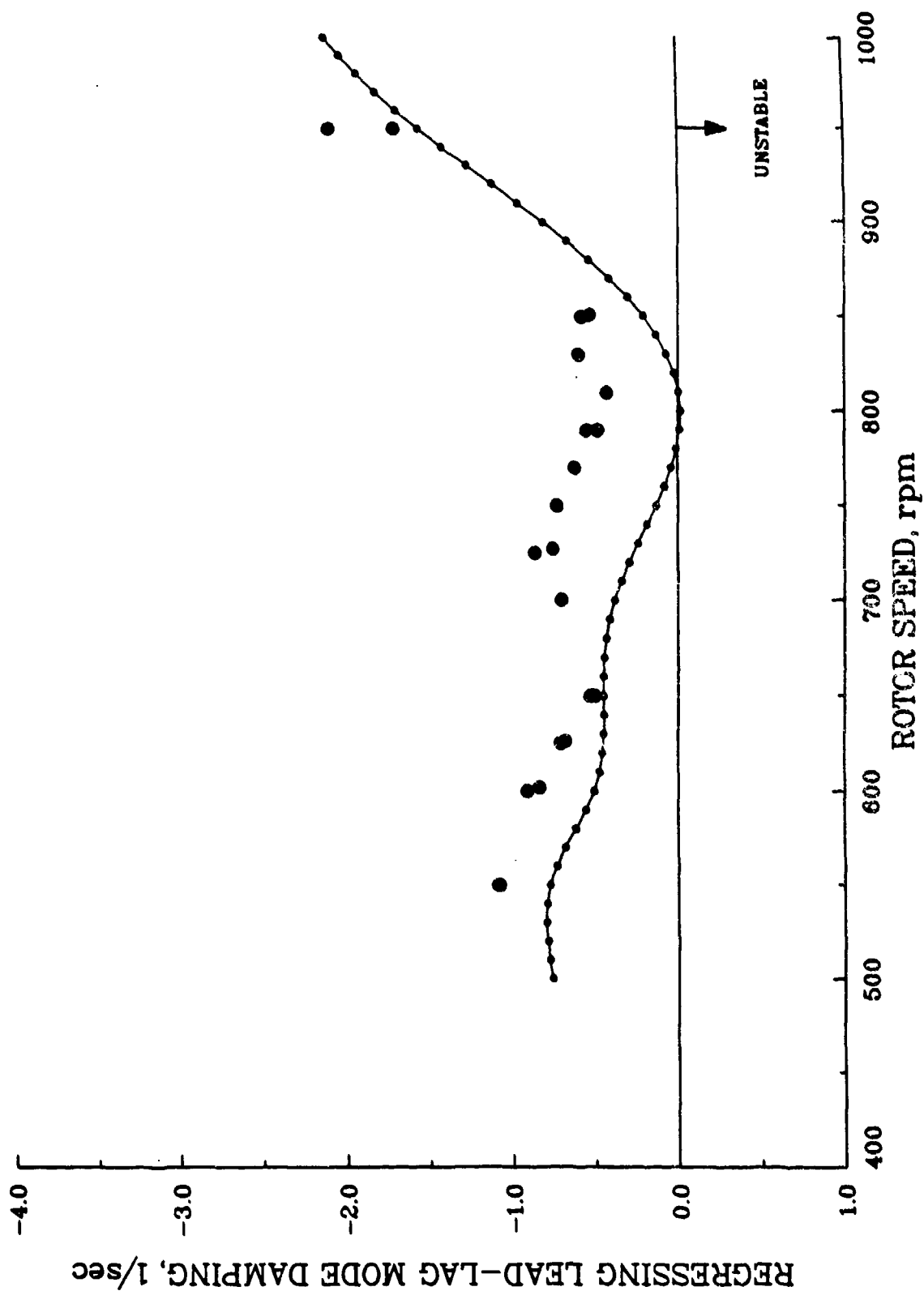
MODAL DAMPING - TASK 86j  
 CONFIGURATION 5, PITCH ANGLE = 9 deg  
 U.S. ARMY AEROFIGHTDYNAMICS



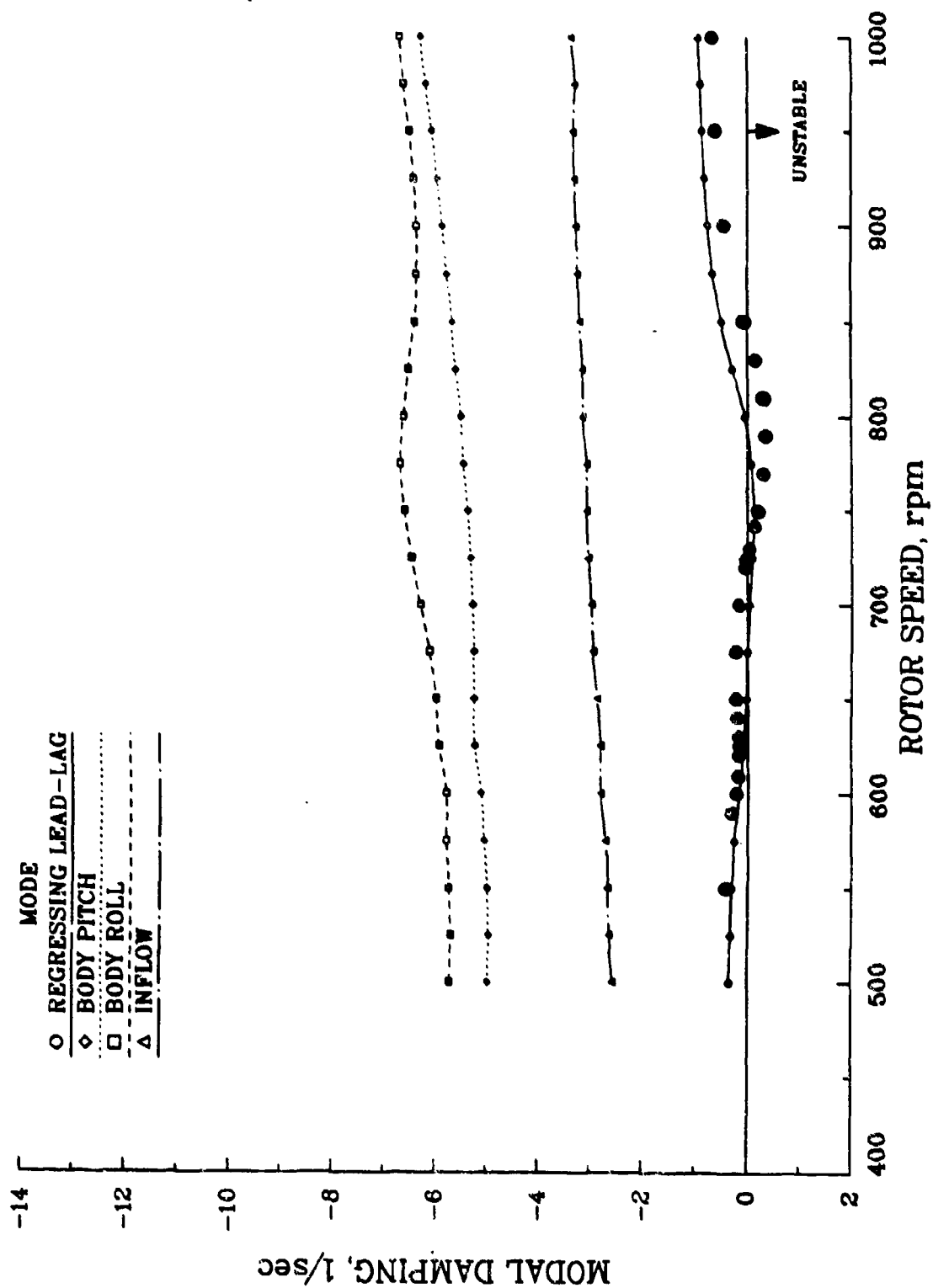
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 U.S. ARMY AEROLIGHTDYNAMICS



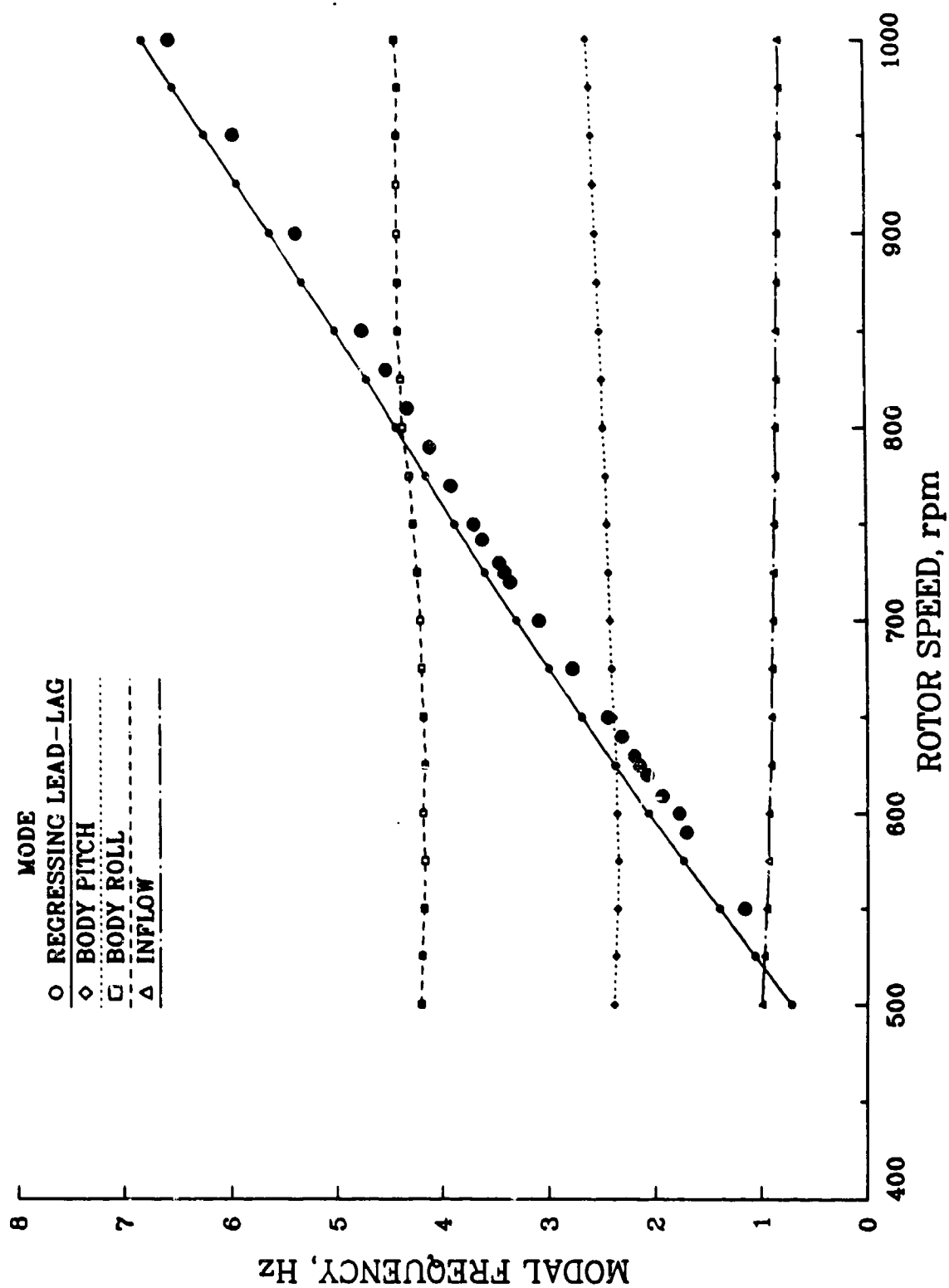
REGRESSING LEAD-LAG MODE DAMPING - TASK 86j  
 CONFIGURATION 5, PITCH ANGLE = 9 deg  
 U.S. ARMY AEROFLIGHT DYNAMICS



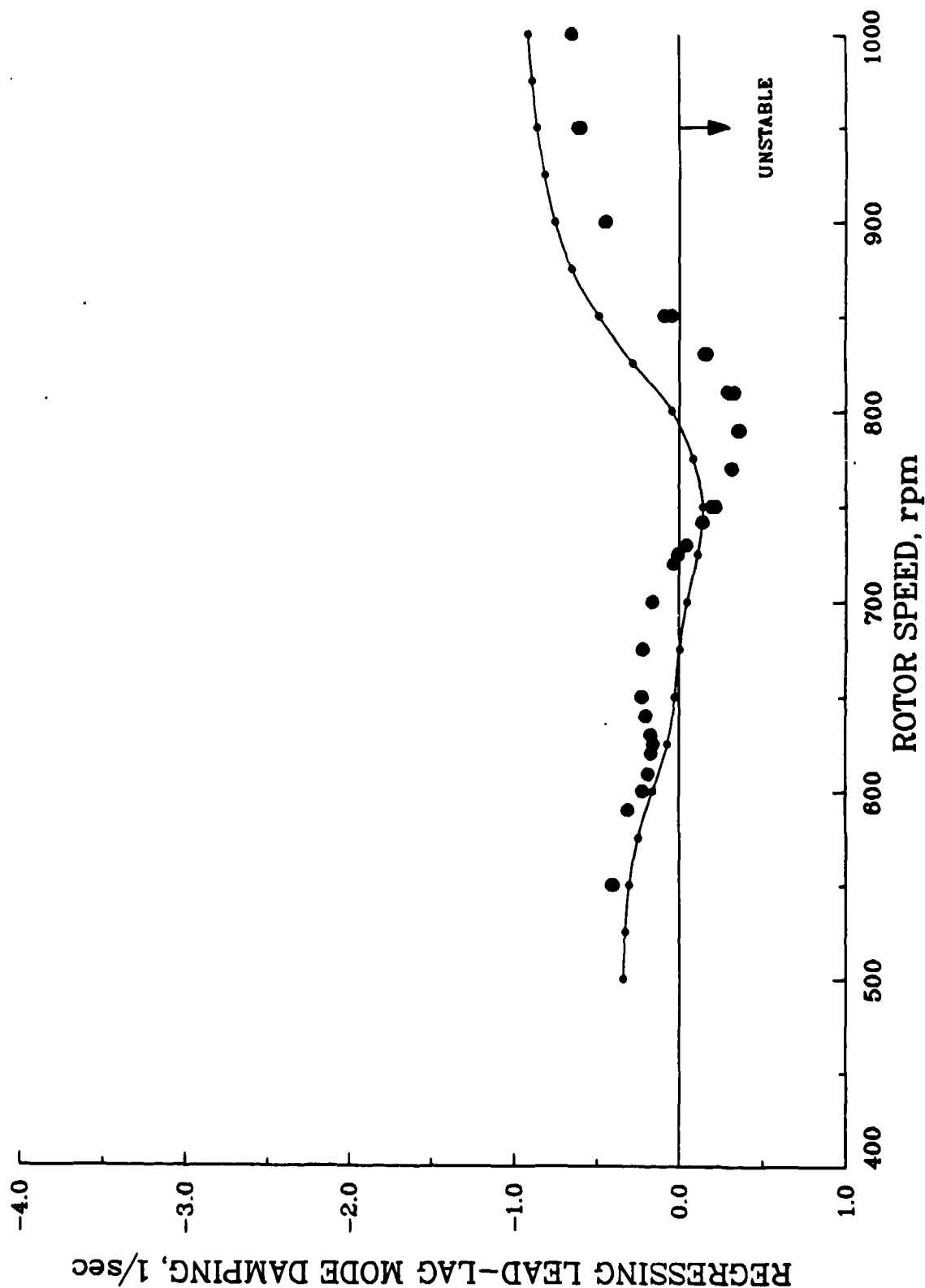
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 BELL HELICOPTER TEXTRON



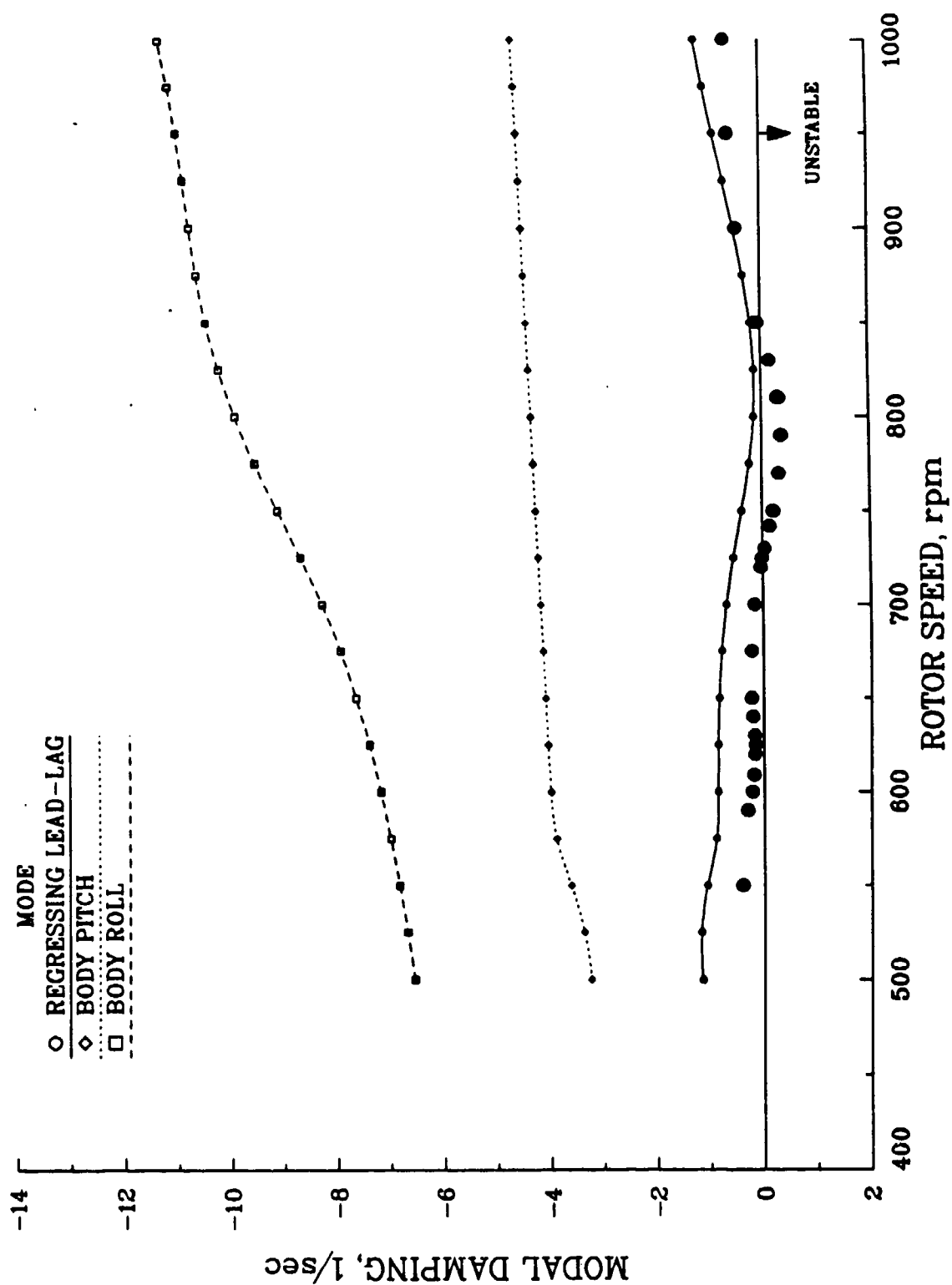
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 CONFIGURATION 5, PITCH ANGLE = 0 deg  
 BELL HELICOPTER TEXTRON



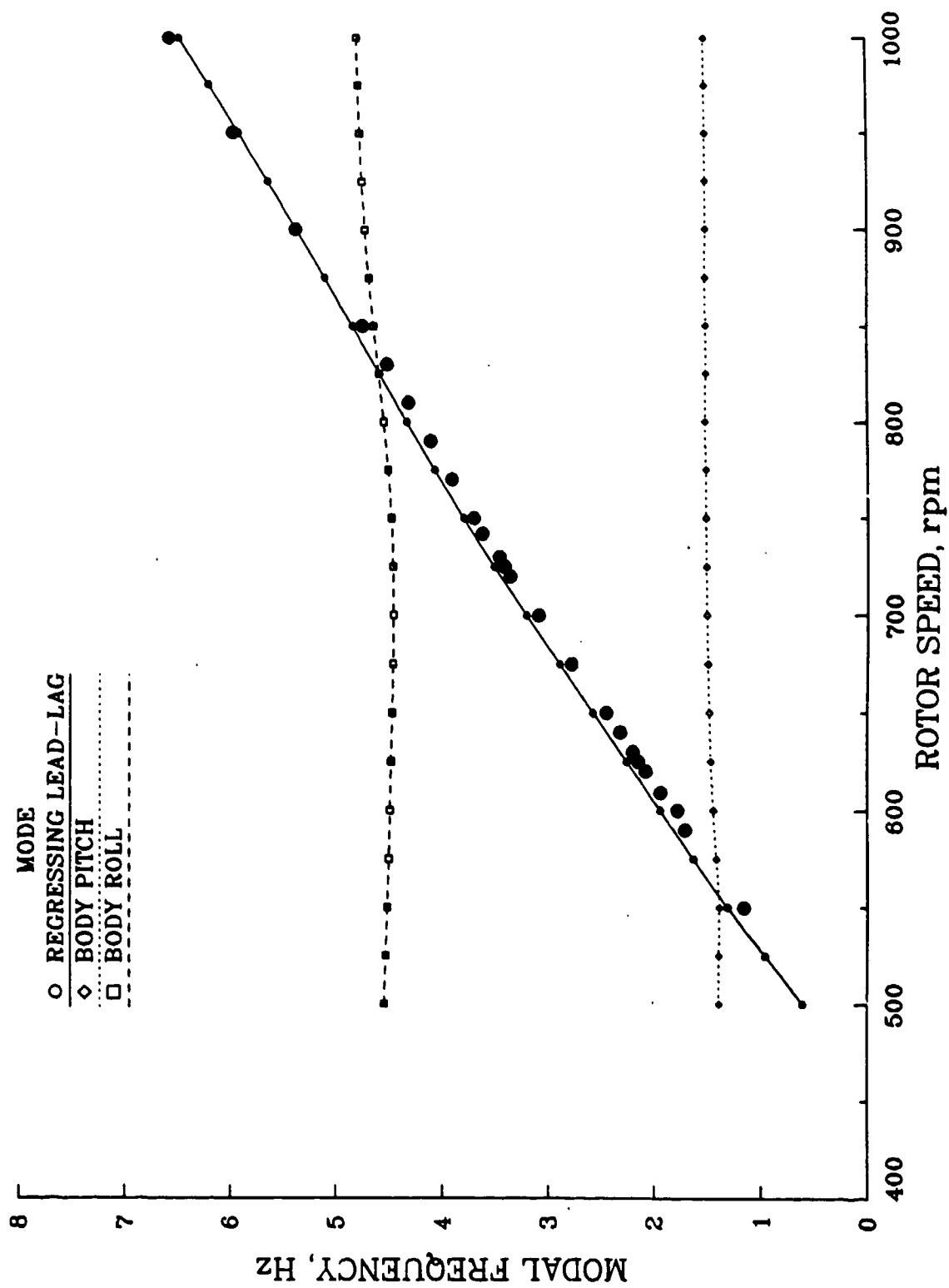
REGRESSING LEAD-LAG MODE DAMPING - TASK 86k  
 CONFIGURATION 5, PITCH ANGLE = 0 deg  
 BELL HELICOPTER TEXTRON



# MODAL DAMPING - TASK 86k CONFIGURATION 5, PITCH ANGLE = 0 deg SIKORSKY AIRCRAFT

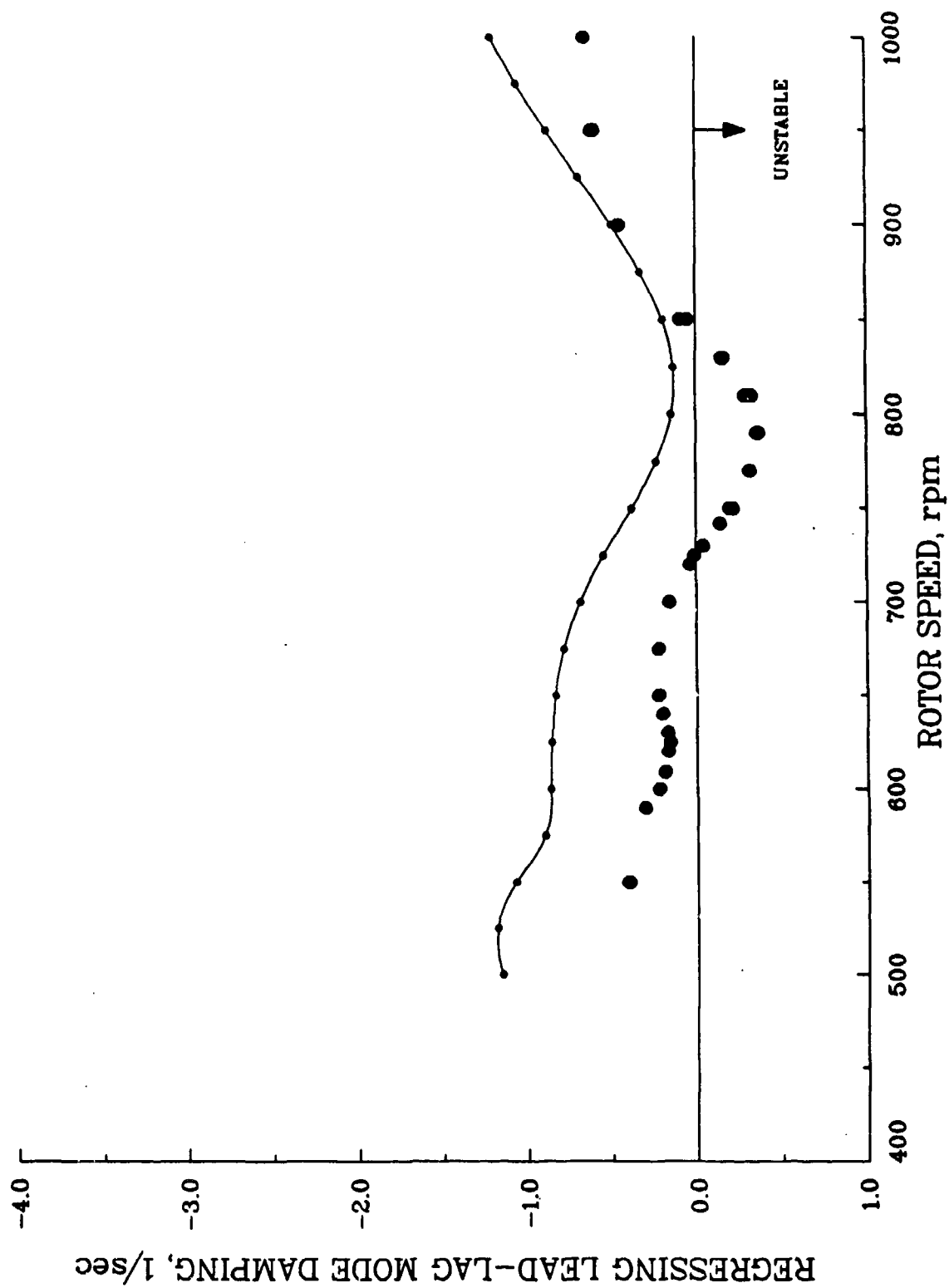


MODAL FREQUENCY - TASK 86k  
 CONFIGURATION 5, PITCH ANGLE = 0 deg  
 SIKORSKY AIRCRAFT

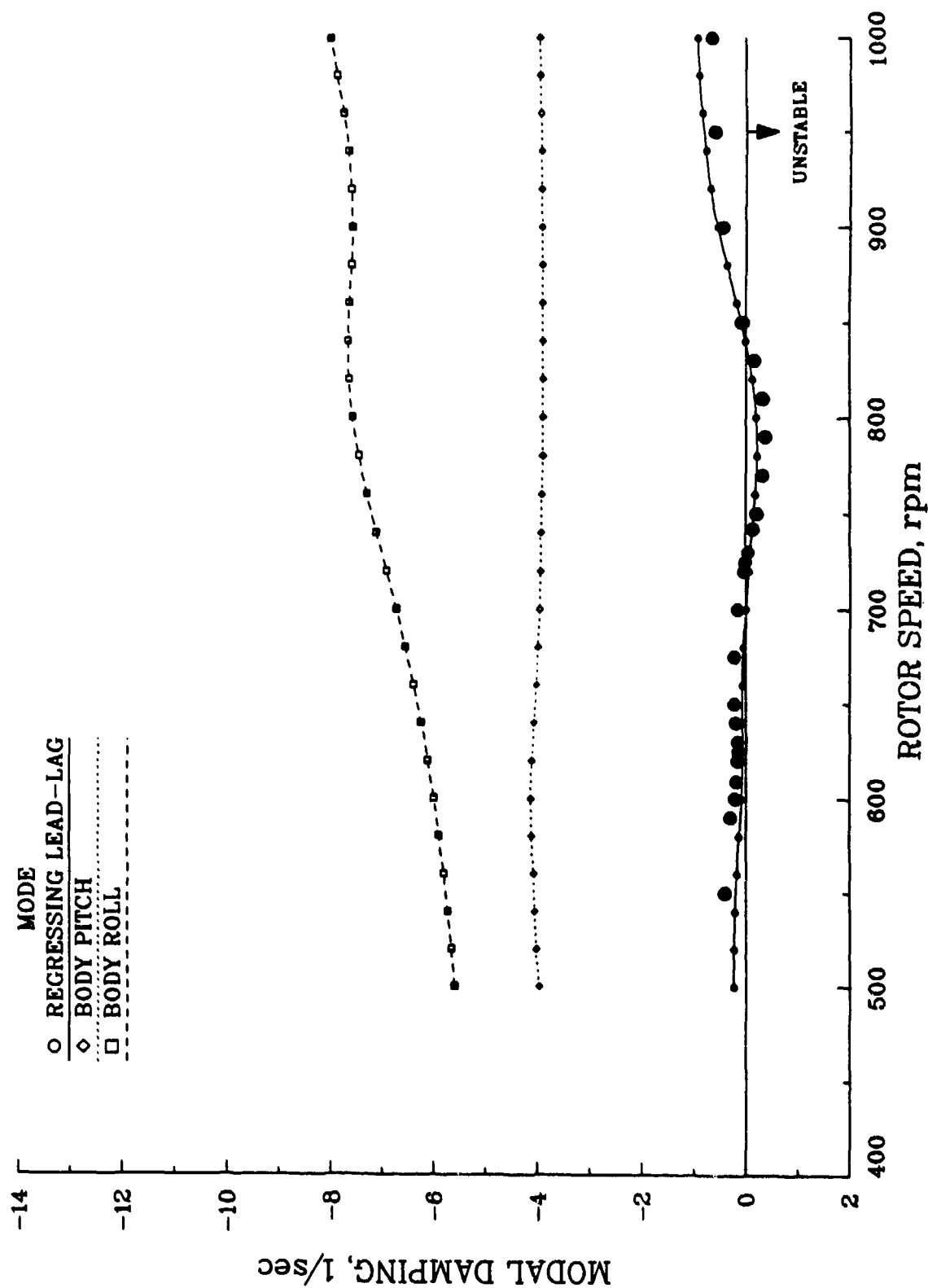




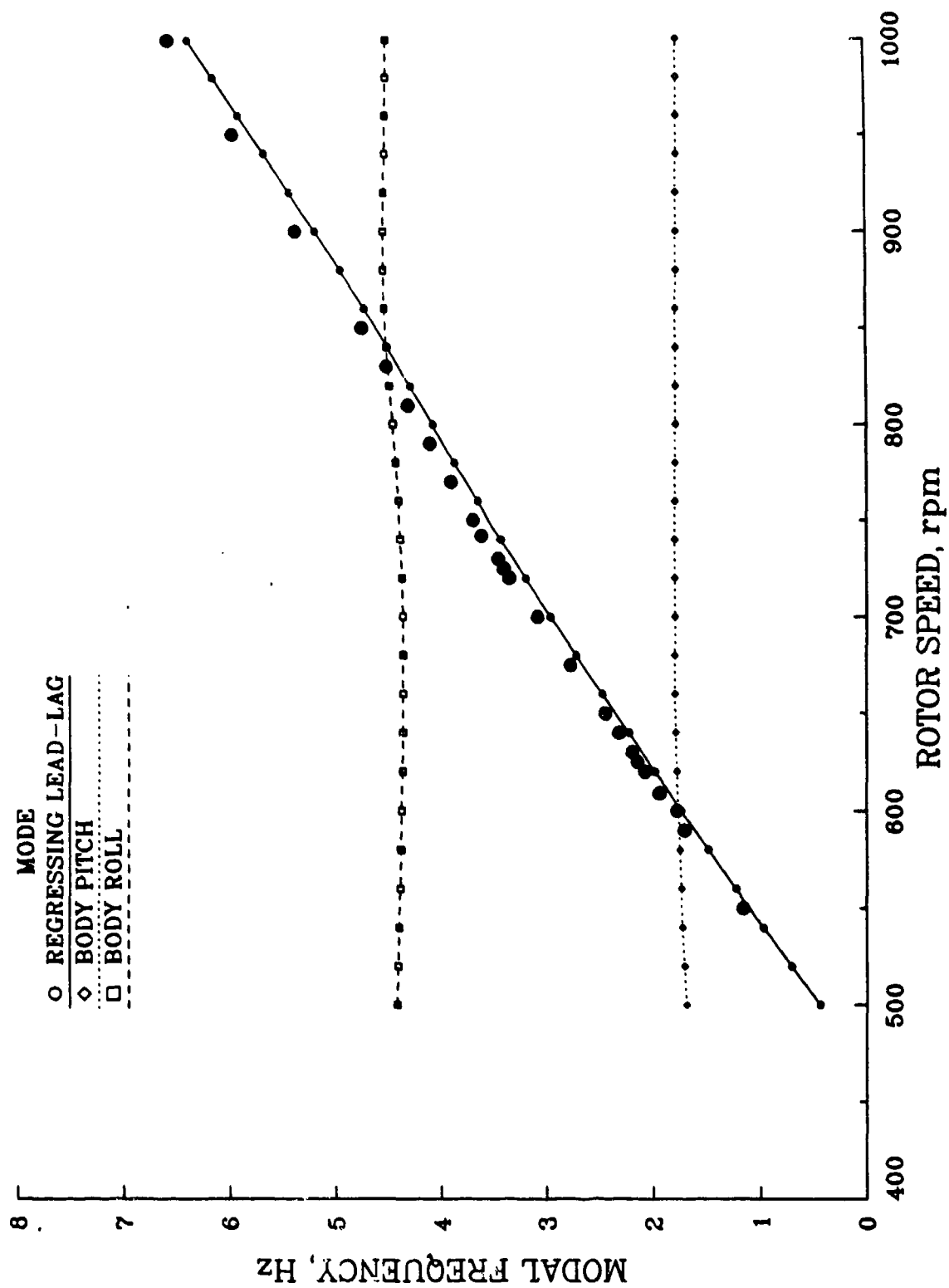
REGRESSING LEAD-LAG MODE DAMPING - TASK 86k  
 CONFIGURATION 5, PITCH ANGLE = 0 deg  
 SIKORSKY AIRCRAFT



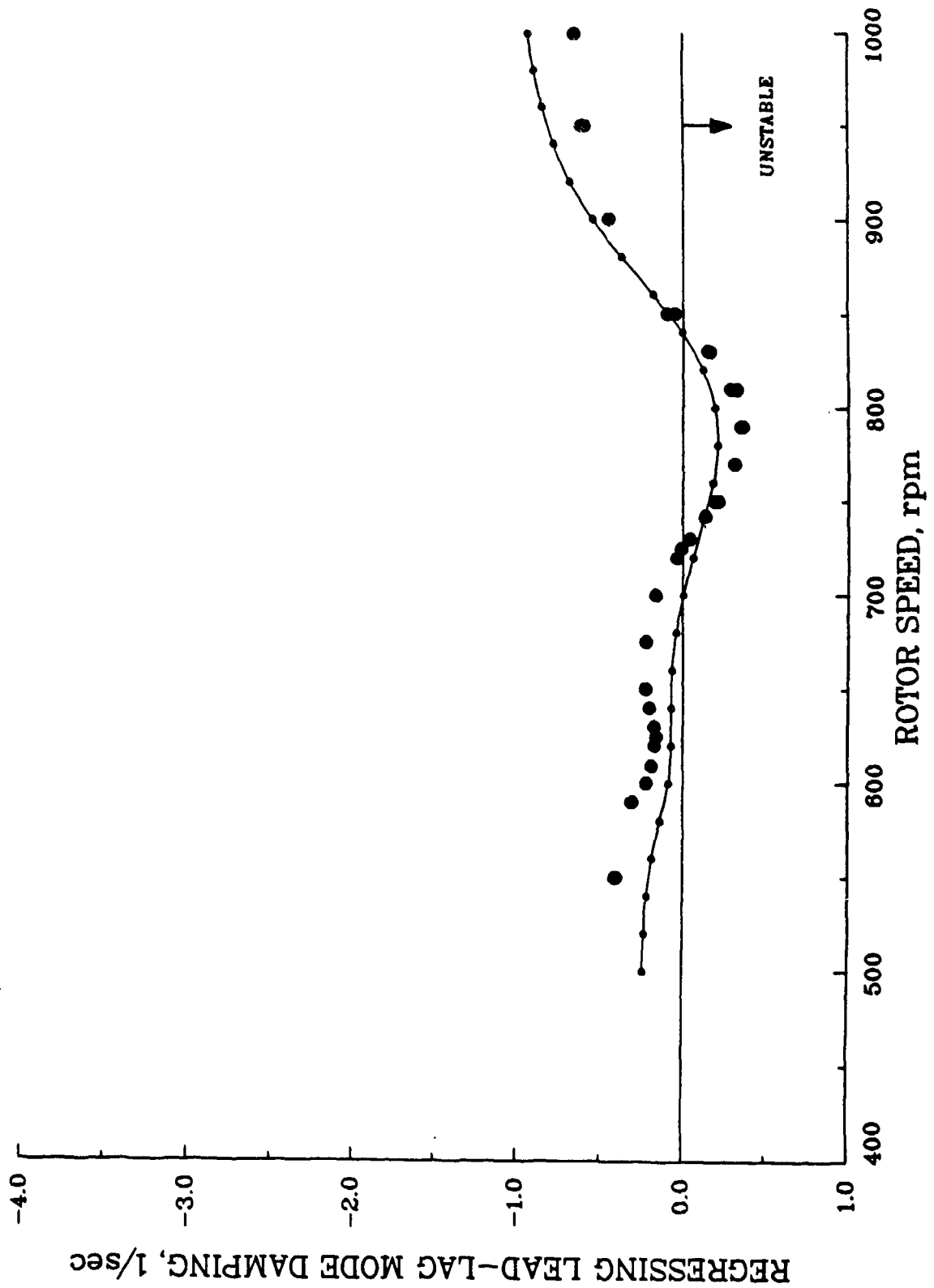
MODAL DAMPING - TASK 86k  
 CONFIGURATION 5, PITCH ANGLE = 0 deg  
 U.S. ARMY AEROFLIGHTDYNAMICS



MODAL FREQUENCY - TASK 86k  
 CONFIGURATION 5, PITCH ANGLE = 0 deg  
 U.S. ARMY AEROFLIGHTDYNAMICS



REGRESSING LEAD-LAG MODE DAMPING - TASK 86k  
 CONFIGURATION 5, PITCH ANGLE = 0 deg  
 U.S. ARMY AEROFLIGHTDYNAMICS





## Report Documentation Page

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16. Abstract <b>Helicopter rotor aeroelastic and aeromechanical stability predictions for four data sets were made using industry and government stability analyses and compared with data at a workshop held at Ames Research Center, August 2-3, 1988. The present report contains the workshop comparisons.</b>					
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